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Vol. 34 July 1942 No. 7

A Platform for the A.W.W.A. in the Coming Year

By Abel Wolman

Stenotypist's record of extemporaneous address on Wednesday evening, June 24, at the Chicago Conference, by Abel Wolman, Dr.Eng., Professor of Sanitary Engineering, Johns Hopkins University, and president of the American Water Works Association.

Mr. President, Ladies and Gentlemen:

I know that the ordinary sequence of events finally brings an out-going president to this particular moment after running out of prize cups, certificates and buckets. I must indicate to him and to this audience in advance, therefore, my tremendous appreciation of your gesture in standing and of your obviously benign applause. I wish that it had been legitimate.

I hate to introduce this tone of doubt, but I looked up the constitution of the Association this afternoon in between the many sessions which are imposed on our members and I find it states that, after an incoming president has been duly certified for a period of probation over some six months, he is to take office on the stroke of midnight on the last day of the convention. I think our out-going president has just slid down the hill more rapidly than his constitutional prerogative would seem to permit.

I appear before you, therefore, this evening largely as a premature and perhaps even an illegitimate child. From the little medical knowledge I have, I believe that what is normally done with a premature child is to stick it very rapidly into an incubator and wait until it arrives at a sufficient weight, stature and lusty lungs to appear before your group. This really is in the nature of a preview, therefore, and it ought to be handled in that fashion.

I am interested in this prematurity of my appearance for another reason. One of the jobs to which I was assigned some years ago, and which I still keep, is on the Board of Direction of the Association for Planned Parenthood. I never thought I would have an opportunity to use that job. It was originally designed, as those of you know, to space the appearance of children on a planned basis. I am the first indication of the failure of that Association.

But since I am here in a perfectly delightful hall with obviously delightful people, I want to take advantage of the opportunity to do some experimentation. Since we have 24 hours before I am legitimatized, I thought I would use that period in talking out with you what a presidential platform might have been if I had been officially inducted into office this evening.

I want to discuss it with you, as it were, in the bosom of this intimate family dinner. I confess it must appear that the collective bosoms of such a large family—almost a thousand—can hardly be intimate, but intimacy can be stretched.

Shifting Our Emphasis

What I want to talk to you about is just what kind of platform a president really ought to design. Sometime when I get back home I shall try to write it out as a result of our joint conversation and then have it mailed through the kindly secretary's office, provided, of course, it meets his editorial scrutiny, which isn't easy to do.

I am not searching for a platform, perhaps characteristic of a Republican Party platform. In other words, I am not searching for one which would result in my being defeated were I running for office. Equally obviously, in a professional society, I do not want a platform which is of a rabble-rousing type. On the other hand, in these days of stress, and they are days of stress perhaps unmatched in the history of our country, I can't get very excited, for example, about a purely intellectual pursuit of the problem of spacing of fire hydrants. Under normal times that would be a reasonably fine basis for a platform and of all the things that should accompany it, but it seems to dwindle in importance in relationship to the world at large.

If I might diagnose the interests of the members of this Association, there are several roads which I might travel, several indices which might be useful to me. One of these is implicit in the program of the past week. As I ran through it during the last day or so in the preparation for a possible platform, I found any variety of things on which a man could take a position —the selection of superintendents, the mutual aid program, how bottlers protect those people who travel to Room 2501 or 2504 during a convention. The profession has taken due precautions that those of you who can leave that room at 2:00 or 3:00 o'clock in the morning can be assured that the

worst that would happen to you in the morning is a headache. You are safeguarded against the natural epidemic diseases by what the Association has done through its laboratories and through its discussions.

We listened to problems of corrosion. We heard of locomotives. We even talked of stabilizing lime with soda water. Those are the foundations upon which our members operate. They seem in the repetition to be purely technical. They represent, however, that thin crust of civilization on which our American public lives and survives, but they still do not seem to me to be the logical or appropriate kind of platform for these days of stress.

We live in a shifting world, in a world which is in a terrific struggle between two ways of life. So, I may be pardoned if I depart from what may be a more appropriate technical subject to what some people like to call glittering generalities. But in this world these generalities appeal to me at the moment, and I am sure appeal to everyone in this room. There appear to be no substitutes for general truths in times of real crisis. This doesn't appear to be the time for us to discuss from a platform basis to the *n*th degree or to the fifth decimal point the strictly technological aspects of our program. It seems much more fruitful to discuss with you these glittering generalities in the hope that they may be brought home to our membership and around which we may be able to build a platform for this coming year of trial and tribulation.

Victory—The Only Plank

As I see it, the problem of this Association—to which I want to lend what meager efforts I may have to offer—is to determine where its membership stands with respect to the country as a whole and to society in general. I choose that theme with a definite purpose and perhaps in extending it I may be a little bit more frank than such an occasion normally may warrant. I do it, however, with full understanding that the room is filled with friends—that it is filled with Americans—that it is filled with people who have a due recognition of their responsibilities.

The first and perhaps the only plank in a prospective platform for the Association during the coming year is victory for our way of life. And whether that victory is won by our giving up three-quarter-inch service pipe or failing to extend our pumping stations—or even in spite of the contests for priorities—or if some of our streams remain polluted or if some of our valves are free of copper or brass, or even if we have to give up the metering of water supplies (heaven forbid) I am quite sure that this group—man, woman, and child—will give them up with joy, with understanding and with one truly primary purpose in mind.

This is not solely *my* platform. I am merely taking the liberty of enun-

ciating what I am quite sure you would indicate to me would be *your* platform, if each of you had an opportunity so to state to me. My only contribution to it during the coming year will be to try to follow in the footsteps of my predecessors, whose leadership and maturity—in balance, in judgment, in intelligence and in sympathy—I shall try in some fashion to emulate.

So, therefore, repeating very briefly, the platform, which is yours and which as I say I shall try to follow, is that in our proceedings and, more important, deep in our hearts, humanity will come first. The American Water Works Association's problems will be considered only insofar as they can stimulate and move forward the aims of embattled society. They must come second until our way of life has been adequately secured and permanently protected.

I make this comment because I think we tend, as all of us do in the technical professions, to insulate ourselves from society in general and from common people in particular. That is not a charge; it is perhaps a diagnosis. The professional, long operating at the will of people, long granted special privileges by the people, tends to forget the source or the purpose of that privilege.

I merely aim again tonight—in discussing this within this family party—to recall that we are here by virtue of the common consent of the democratic people of the United States. What they ask of us, we must give. We must give it not grudgingly, not hesitatingly, not in criticism, but as servants, as agents of a universal parent. That is the kind of platform on which I am quite sure that this Association will rest in the future as it has for somewhat over 60 years in the past.

Accent on Humanity

The best professional performance of this group is for the good of the people of America. It cannot be limited or encompassed by our own desires, by our professional jealousies, by our insistence on the norms of peacetime periods, by the accumulation of goods in the water works field for the protection of specialized sectors of the continent, by failures to recognize major dangers to all that must be important to us.

That platform likewise implies a shifting from our decimal points to the field of human relations.

The English poet Stephen Spender recently, in a very brief poem, expressed it as the battle between technological and statistical interest and humanity in general. He says that as he lay in bed in a hotel such as our own, with flowered walls, with bombs falling in England, he picked up the daily sheet and read there the lists of names of men maimed and killed. He returned to his reading quite undisturbed by this statistical rehearsal of death and of destruction. He recalls for all of us, as I am at-

tempting to do here this evening, that this wedding to the statistical tends to deprive us of human understanding, responsibility and suffering.

The Association will escape from that objectivity, I hope, and move toward the acceptance of the truths of human relations. I need only point out that this is not a hard task for us to pursue. Always—engineering has been a social science. It is as inevitable in our type of life as death and more permanent even than taxes. It is on such a platform, ladies and gentlemen, that I hope to ride through the coming year with you. I have attempted this evening to stress those features of it which are perhaps understressed in normal technical programs, not because they are new or unacceptable to you, but because our daily pursuits sometimes blind us to our present realities and dangers.

Before I sit down, I want to take this one last opportunity to indicate to the local committees, both ladies and gentlemen, the distinct appreciation of the Association and all of its members for the obviously successful preparation which they made for this session. Such lightness, such joy as we can get during these times, have been ours not only to ask for, but to accept. I thank them and you.

Mr. Howson asks me to make one more statement. Plans will go forward as far as we can see at this moment for a similar Conference in 1943. All of us hope that victory will be ours and the world's by that time. The type of Conference, the length and even its actual occurrence will naturally and necessarily be adjusted to the contingencies of the time.

U.S. Water Supply Practice

By A. E. Kelso

Abstracted by Sterling S. Green

IN CONNECTION with formulation of plans for the Upper Yarra project for the City of Melbourne and the Metropolitan area, A. E. Kelso was detailed to make a report on recent developments in American water supply practice. Mr. Kelso's observations cover very thoroughly the design, construction methods, and performance features of water supply and distribution structures. In order to make the report more comprehensible to the reader, standard procedures are described covering the fields of dam building both in concrete and rolled earth fills. Recent developments in dam design and construction practice are given special emphasis.

This report is of great interest to engineers engaged in the field of soil mechanics, particularly as applied to earth-fill structures. The author was able to visit organizations actively engaged in dam building throughout the entire United States and was in a position to evaluate current theories and practical applications of soil mechanics.

Concrete dams are discussed more generally from construction and general design considerations.

I. Structures for the Control of Water

1. Investigation

Geological Investigation

Geological investigation should reveal every relevant circumstance of the origin, history and structure of the soil and rock at the site. Geophysical methods, originally devised for deep prospecting for ore and oil deposits, have recently been applied to the exploration of foundations. These are known as the seismographic and resistivity methods.

An abstract of *Report Concerning Water Supply Practice in The United States of America*, by A. E. Kelso, Engr. of Water Supply, Melbourne and Metropolitan Board of Works, published in Australia in 1941; abstracted by Sterling S. Green, Jr. Civ. Engr., Bureau of Water Works & Supply, Los Angeles.

Investigation by Sampling

While the less costly and less detailed geological and geophysical methods are valuable for preliminary investigation, the final examination of both foundation and materials for construction must be made by inspection of samples and testing of them, and, if possible, by inspection of strata in place. Sampling is effected by hand augers, power driven augers, wash sample drilling and core drilling. Trial shafts are sunk and trenches and tunnels excavated for the purpose of inspecting strata and obtaining samples of them. Disturbed and remolded samples provide information concerning the physical properties of the materials, but, to determine the properties of the foundations as a structural unit, the samples should be tested in their original condition of moisture, consolidation and stress.

The rock in foundations is usually examined by core drilling. The cores from diamond drilling are about 2 or 3 in. in diameter, and cores from shot drilling, about twice that size. Where heavy loads and high water pressures are to be sustained by foundations and close inspection is desirable, large shot-drills or calyx drills are used. By this means a clean hole up to 4 ft. in diameter and 100 ft. deep is obtained. Sequence, inclination, nature of strata and the presence of pockets, faults, etc., may be studied in detail.

Model Studies

In recent years model studies have become a regular part of design technique, being employed in the investigation of a great variety of problems. Models connected with major hydraulic structures have been of the following types: (1) hydraulic models, (2) structural models, (3) models of earth dams—combining hydraulic and structural features, (4) photoelastic models and (5) electric-analogy models.

1. Hydraulic Models: The commonest form of hydraulic model investigation is the inspection of flows at all stages of discharge. By this means may be studied such properties as depth, velocity, pressure, scour, turbulence of flow, the presence of standing waves and the discharge capacity of the structure as well as the effect on these of alterations in dimensions and shape and in methods of operation. The U.S. Bureau of Reclamation laboratory at Denver and the U.S. Waterways Experiment Station at Vicksburg have been leaders in hydraulic model investigation. The spillway at Grand Coulee dam has been designed for a flood of 1,000,000 cfs. and involves the dissipation of 32,000 hp. of energy. Model studies were the basis of design of the dissipators, the scales of models being 1:184, 1:40, 1:15 and 1:120. The more important tests were made on 1:40

model. Tests were made of hydraulic jumps and bucket dissipators of different dimensions, with and without baffles. In the selected design, a bucket, 50 ft. in radius and without baffle piers, was selected. This arrangement causes dissipation of the energy by formation of a high boil above the lip and a large roller in the bucket.

Hydraulic models are constructed of a variety of materials. For models of pipes and conduits, use is made of transparent substances known as "Pyralin" and "Lucite." The great advantage of such materials for this class of work is that, while they are easily worked, tough and strong, they are transparent, permitting the flow within the model to be inspected and photographed.

2. Structural Models: Structural models have a variety of uses, but the most important is the quantitative determination of stress, strain and deflection under complex systems of loads and restraints. In the Boulder Dam models, strain measurements were made in all directions on the upstream and downstream faces, and radial, tangential, and twist deflections, for full and partial loading. The purpose of these measurements was primarily to check the trial load method of analysis which had been developed in the structural design.

3. Models of Earth Dams: Earth-dam models have been constructed as exact replicas of their prototypes and composed of prototype materials (i.e., materials consolidated in place to the same density, moisture content, etc., as in the actual structure) in order to study the flow of water through the structure, the line of saturation, pore pressure, behavior in filling and emptying and the swelling, shrinkage, softening and drainage characteristics of the material when subjected to prolonged saturation. Other models have been constructed of standardized materials, such as clean sand on a sand or gravel foundation, to check particular theories of stability. In these, the dimensions and structure of the model are usually made in such manner that, in theory, they should produce failure in a particular manner. By the due occurrence (or otherwise) of that type of failure the theory is checked.

4. Photoelastic Models: Analysis of stress by this method depends on the production of photoelastic patterns when polarized light is passed in a certain manner through a transparent medium under stress. The simplest and commonest type of model is a two-dimensional one, cut from clear bakelite. The model is put in a frame and loading similar to that occurring in the prototype is applied. From the disposal of the fringes it is possible to deduce the zones of compression and tension, and from their number, a quantitative measure of the differences in principal stresses from point to point. At boundaries, where one of the principal stresses is zero, the other stress is determinate.

The magnitude and direction of both principal stresses at points *within* the model can be determined by means of the photoelastic interferometer. In this, interference fringes take the place of isochromatic fringes referred to above; and the measure of change in stress is not the number of them, but the number which moves across the field of the instrument when load is applied. For the analysis of dams and similar structures where weight of the material determines dead-load stress, the strain of bakelite is insufficient to produce patterns. For this purpose gelatin has been used with good results.

5. Electric Analogy Models: By mapping the lines of equal potential within a model constructed in a particular manner it is possible to study the lines of flow of water through the prototype. This method will be discussed in a later section.

2. Foundations

The data obtained from investigations such as those described above are used in examining the stability of foundations under load and under the action of percolating water. The processing of foundations, the provision of foundation drainage, and the grouting of rock bases with cement or other materials are the methods commonly adopted for controlling seepage and uplift and for increasing stability.

Stability of Foundations

When the physical properties of the foundation materials have been determined, an analysis is made of the stability of the foundation under the loading imposed by the structure and the water. Photoelastic models are used in confirmation of the results of analysis.

Processing

Foundations for earth dams are sometimes grouted to make them more watertight, but not usually to render them more solid or stable. Under superimposed loads on fine clay foundation material consolidation may take place more rapidly than drainage can be accomplished, resulting in high pore pressures and a decreased shearing resistance of the foundation. This type of weakness may be offset by distributing the loading on the base or by drainage, but neither foundation grouting nor any other direct method of processing is effective. At Franklin Falls Dam, tests revealed that the foundation sands and gravels were in a very loose state and of a density well below the critical density corresponding to the loading under the completed fill. It was therefore decided to compact the whole foundation by the use of explosives. Charges consisting of a number of sticks of 60 per cent dynamite were jetted into the ground at a spacing of

20 ft. in each direction, generally some 15 to 20 ft. deep. They were then fired simultaneously, repeating the procedure on four intermediate grids of the same spacing. The average settlement recorded was about 2 ft. over the area and it is believed that not only has there been a substantial decrease in permeability, but the risk from "liquefaction" of the foundation has been greatly decreased.

Foundation Drainage

The Franklin Falls Dam is also interesting for the impervious upstream blanket which is used to increase the travel of seepage water. There is no cutoff, but a trench has been provided under the pervious downstream bank with its invert at river level. The trench is to be filled with coarse gravel, and will act not so much as a drain for the pervious downstream bank as a collector for the seepage through the foundation. There is a substantial rock toe, protected underneath by a filter, to collect the upward flow from the foundation downstream of the dam and to prevent piping. This system, combined with the added safeguard of a steel sheet-pile cutoff, is used at Denison Dam.

Grouting

In preparing the foundations of large masonry dams, low pressure grouting is carried out over a substantial portion of the base to make the upper crust of rock solid and to tighten it against subsequent high-pressure grouting. The concrete is then placed up to a certain height (in some instances 200 to 300 ft.) and the first series of holes for the grout curtain is drilled through pipes set in the concrete. Grouting proceeds in the stages necessary to insure retention of grout at the ultimate pressure. A deeper series of holes, which may be drilled to 300 ft. in depth, is then grouted, also in stages. Behind the grout-curtain, drainage holes are drilled from the gallery or galleries to a sufficient depth at an angle downstream to penetrate to ungrouted rock below the grouted crust. At Shasta Dam no hole is considered completely grouted unless it takes grout at less than 1 cu.ft. in 15 min. The quantity of grout has usually ranged up to 5 cu.ft., although one hole took 70 cu.ft. It is often necessary to calk cracks to prevent excessive loss of grout at the pressure stage. This is done with oakum, wooden wedges, lead wool or other suitable materials.

A recent development associated with grouting is the use of sensitive instruments for measuring displacements of rock or concrete. With the very high pressures used for final grouting, there is distinct danger of the rupture of sections of the rock base or the superimposed concrete. One of the modern instruments used for detecting upheaval is the portable tiltmeter, the principle of which is an extremely sensitive optical system

which magnifies and measures changes in the angle of incidence of a beam directed from a source of light and reflected from the surface of a mercury pool. It is capable of measuring angles of rotation of the plane of its base as small as one second of arc. This degree of sensitivity is sufficient to indicate incipient displacement in advance of rupture. A steady creep in deflection, as long as grouting pressure is applied, is taken as a danger signal.

The grouting mixture is usually five parts of water to one of cement by volume at the start of the hole, thickened as circumstances warrant. A new development is the inclusion of colloidal clay ("Bentonite") to cheapen the mix and to give it swelling qualities.

The grouting machine is usually a duplex positive displacement machine, which draws the grout from a tank containing an agitating device. The tank is fed from a batch mixture.

3. Structures of Earth and Rock

Requirements of Design

In spite of great developments in the scientific study of soils, and in the stability of foundations, embankments and dams, the basis of design of earth structures is as yet by no means well established. As earth is not a homogeneous, elastic or isotropic material, the usual basis of elastic analysis is lacking; and to obtain a solution of the elastic equations of stress for earth materials, it is necessary to make special assumptions. None of the analytical methods has as yet been accepted without reserve. A second obstacle to design is that, even when an appropriate assumption has been made, it is still not possible to assess the stability of the structure with proper certainty, because there is no wholly satisfactory method of measuring two of the most important physical properties which are required for analysis—cohesive strength and shearing strength.

The Physical Properties of Soils

The physical properties which are of importance in the design and construction of earth dams are:

Grading (mechanical analysis)
Density
Moisture content
Permeability (seepage)
Consolidation (settlement, shrinkage, expansion)
Shearing and cohesive strength (pore pressure)
Compaction and penetration resistance
Critical density (liquefaction)

The methods of making tests to determine some of these properties have become standardized, as, to some extent, has the testing equipment.

1. Mechanical Analysis: The significance of mechanical analysis is chiefly in identification and preliminary classification.

2. Permeability: Permeability is measured in several different ways—directly as in the constant head or falling head permeameter or indirectly by computation from the consolidation constants of the material.

3. Shear and Pore Pressure: If a material is moist, and comparatively impervious, it does not drain when it is loaded. Compression takes place by rearrangement of soil particles and by reduction of volume of air in the pores between the particles; but as the fluid pressure within the pores is built up, more of the load is supported by fluid pressure (known as pore pressure). As a result of recent work, the view has been expressed that when pore pressures are correctly determined, it will be found that, for most materials, the tangent of the angle of internal friction will approach 0.6 to 0.7. A considerable amount of work is now being done in many laboratories in America in the investigation of pore pressure and the measurement of shearing strength of soil samples by use of triaxial shear apparatus. This apparatus provides not only for a measurement of pore pressure, but for a study of its relation to normal and radial loads and its rate of dissipation when those loads are removed or when drainage is permitted. Although the work of the triaxial shear machine is only emerging from the research stage it is not too early to say that it holds great promise of a better basis for measuring the shearing and cohesive strength of fine materials and of a better understanding of the provision for pore pressure which it is necessary to make in designing and constructing embankments of those materials. For determination of the shear coefficients, the rapid direct shear test is still generally in use. For coarse pervious materials the results of this test are probably reasonably satisfactory, but for fine materials the results are often inconsistent and unsatisfactory. The governing factor in the determination of the shear coefficients to be used in the analysis of a structure composed of impervious materials is the degree of pore pressure to be expected. The estimation of this, and of the appropriate constants, is still a matter of judgment based on tests and on experience.

4. Compaction and Penetration Resistance. The relations between density, moisture content and penetration resistance of soils were originally expressed by R. R. Proctor in 1933. Since that time they have been used regularly in defining design requirements and in controlling field procedure in the construction of dams. It is usual to determine, by laboratory tests, curves showing the relationship between moisture content and density and

penetration resistance of the soil sample. In general it has been the aim to place the material in the bank at the values determined by the point of maximum density. Recently, considerations of pore pressure and of the possibility of expansion on saturation have raised a question as to whether the so-called optimum point is in fact the most suitable under all circumstances. One contention is that compaction should be effected at a moisture content well below optimum, so that the mixture of air and water in the pores could suffer considerable deformation without the generation of high pore pressures. Against this, it is claimed that with such low moisture contents, subsequent saturation may, by release of capillary forces, cause expansion and heaving. The A.S.C.E. Committee on Earth Dams and Embankments favors the use of too much, rather than too little, moisture. Proctor has concluded from observation of existing structures that the material should be consolidated to such density that at saturation it would have a needle reading exceeding 300 psi. This is called the "saturated needle" value. Any density above this will satisfy the penetration criterion.

Stability Analysis

Two applications of the theory of elasticity to the mathematical analysis of stresses in earth dams warrant mention. Equations of stress along co-ordinate two-dimensional axes perpendicular to the axis of the bank provide two equations which contain three unknowns—the co-ordinate nominal stresses and the shear component. In both methods of computation the Mohr criterion of stability, which expresses the relation that, at failure, exists between the angle of friction, the cohesive stress, the pore pressure and the principle stresses at any point, is used to provide the third equation.

In one method, originated by J. H. A. Brahtz of the Bureau of Reclamation, there is deduced from the fundamental equations the so-called "critical pore pressure," which would exist at any point within the structure at the instant of failure. The criterion of failure is the existence of pore pressure in excess of this. In the other, for which R. A. Glover, also of the Bureau of Reclamation, is responsible, the actual pore pressures are used to determine lines of probable slip and the criterion of failure is the possibility of mapping such a line from one boundary surface to another.

The most commonly used method of analyzing stability is that of Fellenius—generally known as the slip circle or Swedish method. In it is made the assumption that failure will take place on a cylindrical sliding surface and by trial is found that surface on which the greatest cohesive force would be required for stability. This is assumed to be the surface of

failure, so that the stability of the mass lying above it can then be examined. For this analysis, the magnitude of pore pressures and of the shear and other physical constants of the material must be known.

Of all the methods it is correct to say that their limitations are not those of the mathematical treatment of basic assumptions. They should be used only with the fact clearly in mind that they relate to ideal materials and conditions which do not in fact exist.

Seepage Analysis

Studies of the flows to be expected through the structure constitute an important part of the design of an earth dam. After the materials available have been examined and tested, trial profiles are drawn and, using the permeabilities of the several materials, flow nets constructed.

Calculations of flow nets are frequently checked by the use of models or by the electric analogy method. This method depends on the analogy between hydraulic and electric flow, which is mathematically expressed in the fact that the form of Ohm's Law is identical with that of Darcy's Law.

Seepage studies lead to a knowledge of the amount of flow through a structure, the hydraulic gradient through it and the internal pressure within it due to seepage forces.

Types of Structure

Structures may be rock-fill, hydraulic-fill or rolled-fill dams.

1. Rock-Fill Dams: Rock-fill dams are commonest in the Western States, following an old Californian mining type of structure. Some very high structures have been built, as, for instance, the Salt Springs Dam in California, which is 328 ft. in height, and contains about 3,000,000 cu.yd. of rock. Analysis of stability is not used in the design of such dams, the profile being determined by following established practice.

To minimize settlement, it is considered essential that the rock be hard and durable, that it be dumped into position from the greatest possible height and that it be sluiced into place with as much as 2 cu.yd. or more of water to 1 cu.yd. of rock. Settlement results from the crushing of the points of bearing between rocks or from the movement of fine material under load. Dumping and sluicing ensure a solid bedding between large stones, thereby forming a rigid stone skeleton into which the fines from higher up are subsequently washed.

2. Hydraulic-Fill Dams: Hydraulic-fill dams have been built to heights of about 250 ft. The type is a restricted one, as sorting of the materials is largely automatic and the borrow pit must contain, by and large, core (fine) material and shell (coarse) material in about the desirable proportions. Otherwise the core will be too wide and the bank unstable, or too

narrow and the bank insufficiently watertight. On the contrary, in a rolled-fill dam, zoning and independent handling of the several grades of material make it possible to use all suitable grades however they occur in the borrow pits.

It is generally true that materials which are suitable for hydraulic-fill dams are equally suitable for the major parts of rolled-fill dams if not for the whole of them. Until recently the hydraulic process, which in one operation effected the transportation, sorting and consolidation of the material, has been considerably cheaper than any other method of bank-building. With the advent of mechanical plant of large capacity suited to the dry process (rolled fill), however, the latter has become competitive in cost, and is in general superior, not only in the range of the materials which can be effectively employed, but also in reliability, owing to the closer control of the technique of construction which it provides.

The principle of stability of a hydraulic fill is that the fluid mass of the core, for a long time after construction, depends for its support wholly on the stable outer shells.

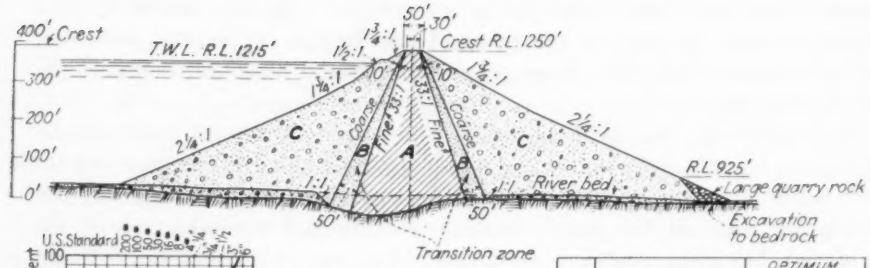
3. Rolled-Fill Dams: Rolled-fill dams have been built, or are under construction, to heights in the vicinity of 300 ft.

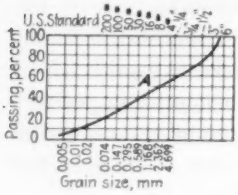
a. Profile: In Fig. 1 of this abstract are shown the profiles of some of the important rolled-fill dams of America. These profiles have been designed to meet the requirements already discussed, the chief of which are density, stability and a suitable degree of imperviousness under the expected conditions of loading and saturation.

It will be observed that the use of several classes of materials in defined zones is common practice and, from the mechanical analyses and descriptions of materials, that well graded gravels are common; whereas fine materials, such as clays, are not as frequently used except in narrow zones. Very few high dams are constructed for the greater part of a single class of material; and, in those which are, the material is usually a well graded gravel and rarely a fine clay.

B. K. Hough Jr., in a paper before the American Society of Civil Engineers at Denver in July 1940, made an important comment on the procedure in the design of earth dams, in criticizing the common practice of designing the dam and then searching for "suitable" materials. He expressed the opinion that almost any material can be made "suitable" if the right design is developed and that the correct approach to design is first to make a thorough examination of every available material, and then to design the most economical section which will utilize those materials effectively.

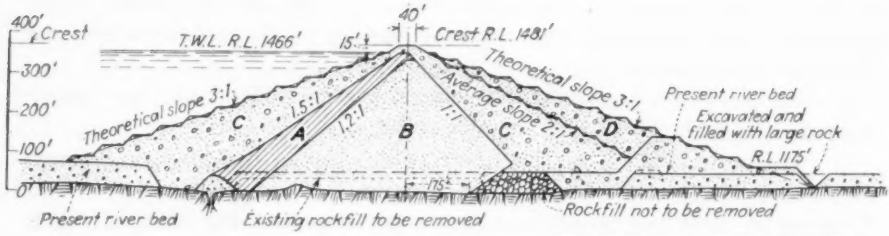
b. Drainage: The permeability of the material to be used determines the amount of leakage, and the position of the flow lines. It also deter-





MUD MOUNTAIN DAM

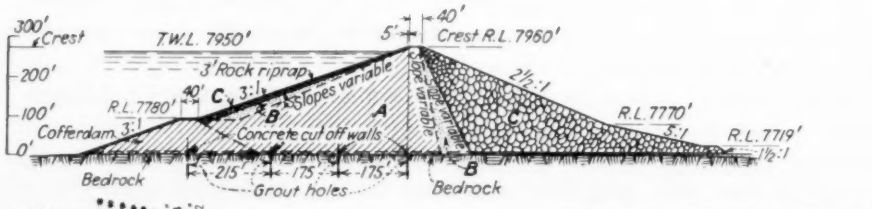
ZONE	MATERIAL	OPTIMUM	
		DRY DENSITY	PERCENT MOISTURE CONTENT
A	Till, sand and gravel	122	13
B			
C	Dumped rock, sluiced		

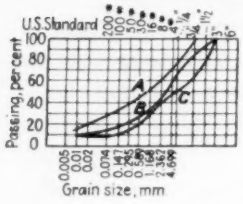


A - 31% passing #200 sieve

SAN GABRIEL DAM No. 1

ZONE	MATERIAL	OPTIMUM	
		DRY DENSITY	PERCENT MOISTURE CONTENT
A	Red, fine clay	115	
B	Screened rock, rolled	120	
C D	Dumped rock, sluiced		





GREEN MOUNTAIN DAM

ZONE	MATERIAL	OPTIMUM	
		DRY DENSITY	PERCENT MOISTURE CONTENT
A	Clay, sand and gravel	129.8	9.3
B	Clay, sand, gravel and cobble. Semi-pervious	126.3	10.5
C	Cobble and rock		

FIG. 1A. Profiles of American Rolled-Fill Dams

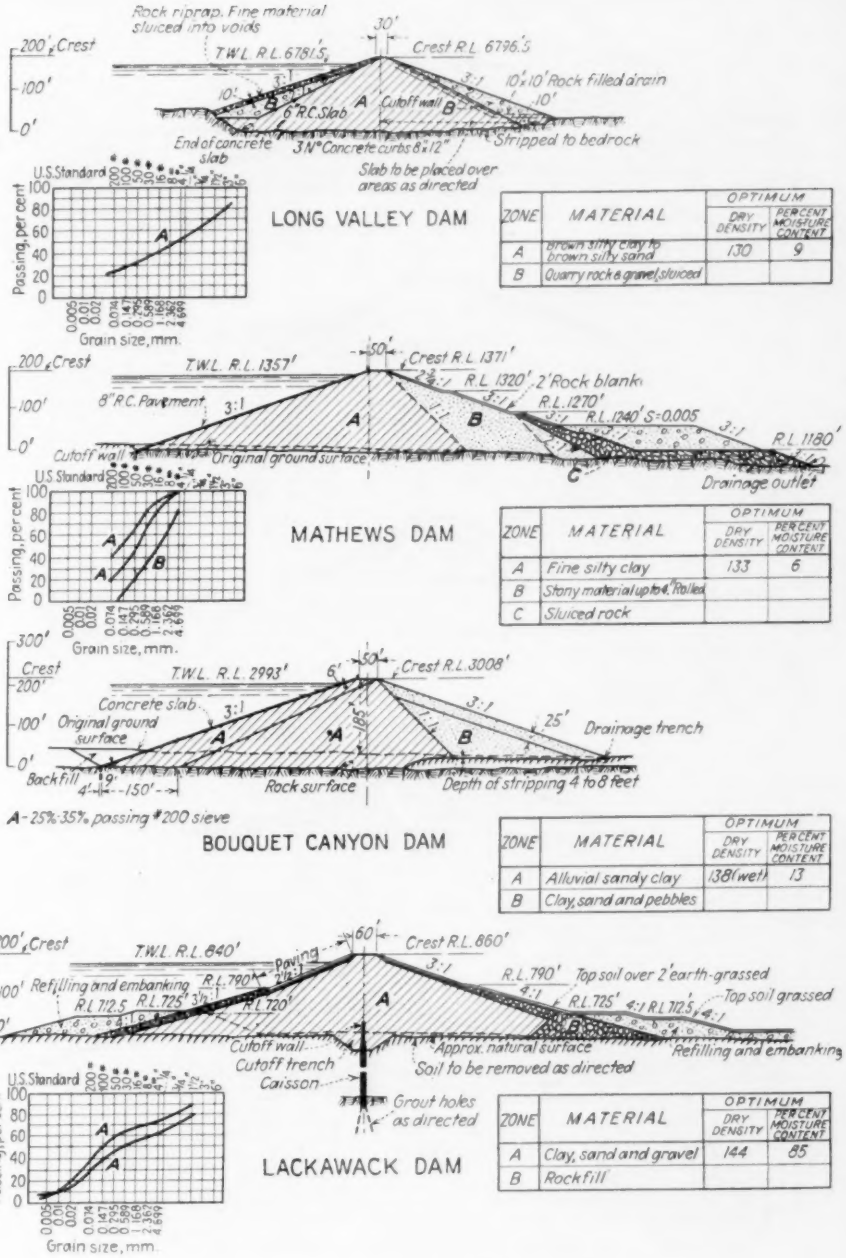
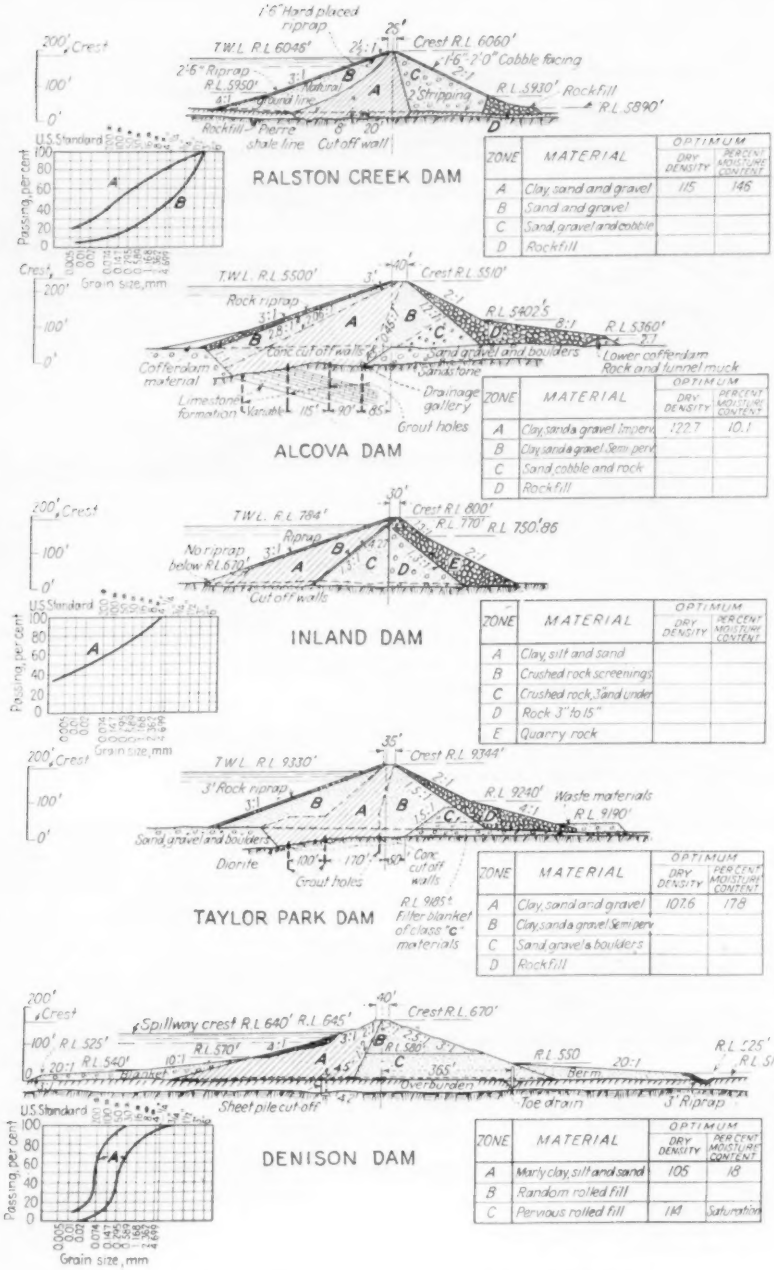


FIG. 1B. Profiles of American Rolled-Fill Dams



ZONE	MATERIAL	OPTIMUM DRY DENSITY	OPTIMUM PERCENT MOISTURE CONTENT
A	Clay, sand and gravel	115	145
B	Sand and gravel		
C	Sand, gravel and cobble		
D	Rockfill		

ZONE	MATERIAL	OPTIMUM DRY DENSITY	OPTIMUM PERCENT MOISTURE CONTENT
A	Clay, sand & gravel Imperv	122.7	10.1
B	Clay, sand & gravel Semi perv		
C	Sand, cobble and rock		
D	Rock fill		

ZONE	MATERIAL	OPTIMUM DRY DENSITY	OPTIMUM PERCENT MOISTURE CONTENT
A	Clay, silt and sand		
B	Crushed rock screenings		
C	Crushed rock, Sand under		
D	Rock 3" to 15"		
E	Quarry rock		

ZONE	MATERIAL	OPTIMUM DRY DENSITY	OPTIMUM PERCENT MOISTURE CONTENT
A	Clay, sand and gravel	107.6	17.8
B	Clay, sand & gravel Semi perv		
C	Sand, gravel & boulders		
D	Rock Fill		

ZONE	MATERIAL	OPTIMUM DRY DENSITY	OPTIMUM PERCENT MOISTURE CONTENT
A	Marly clay, silt and sand	105	18
B	Random rolled fill		
C	Pervious rolled fill	141	Saturation

FIG. 1C. Profiles of American Rolled-Fill Dams

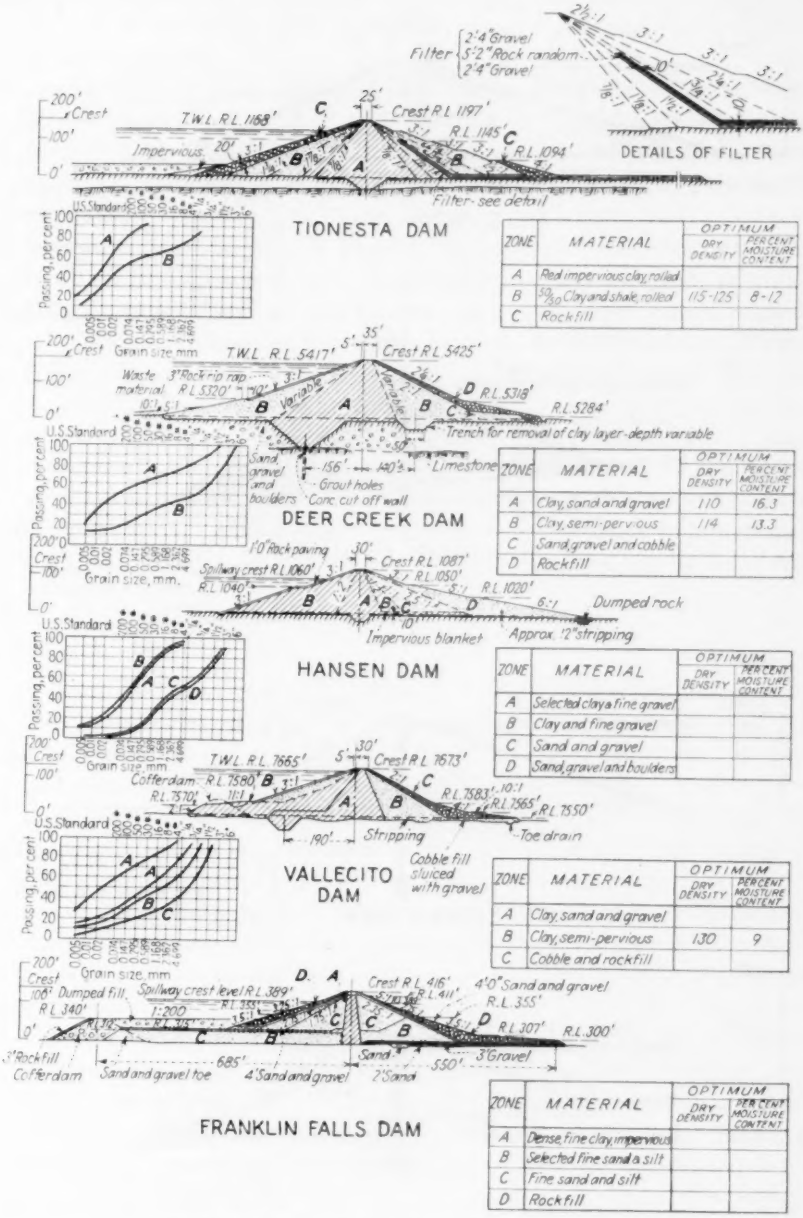


FIG. 1D. Profiles of American Rolled-Fill Dams

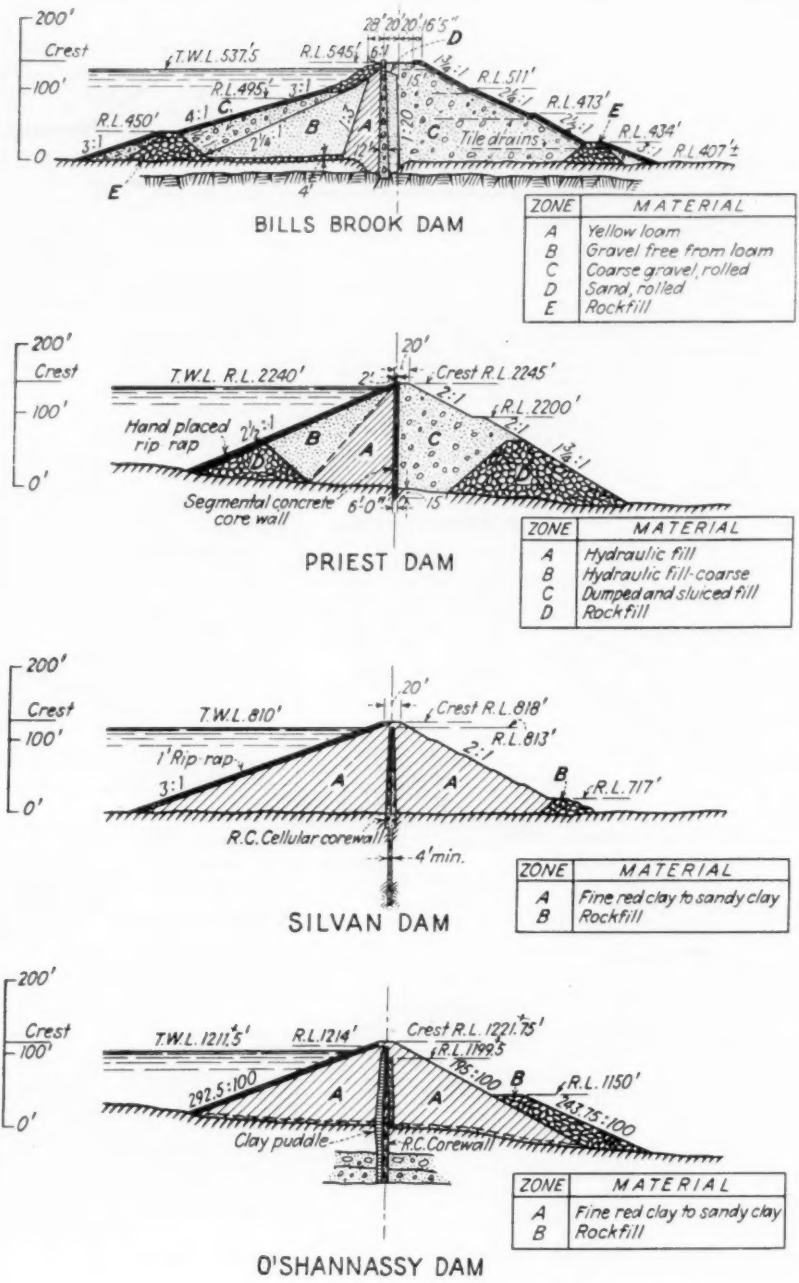


FIG. 2. Profiles of American Earth-Fill Dams With Corewalls

mines the need and the possibility of increasing the stability of the downstream toe by drainage, and the capacity and extent of the system of drains to be provided.

Permeabilities of materials used for the construction of earth dams range from small fractions of a foot per year to many thousands of feet per year. From the point of view of zoning, those under 1 ft. per yr. would be classed as impervious, and over 10 ft. per yr., pervious, i.e., suitable for the outer zones.

c. Corewalls and Cutoffs. In Fig. 2 of this abstract four corewall dams are shown for comparison with the larger modern structures, none of which, it will be observed, have corewalls, although several have cutoff walls in the foundation. Instead of thin concrete walls to ensure watertightness, the latter are provided with zones of compacted impervious material. It is a fact that however well embankments have been constructed, they all settle to some extent and they also usually move downstream to some extent under water pressure. The comparative flexibility of the compacted impervious core material is an important advantage in this respect and the rigidity of a concrete wall a disadvantage, more particularly in a high dam where the deflection and settlement may be expected to be relatively great.

Mapping the Borrow Pits

The investigation of available materials which precedes the design of an earth structure has already been dealt with in a general way and the design of the structure to fit those materials to the requirements of permanence (e.g., stability and watertightness) and use (e.g., conservation or flood control) has been described. Investigation and design proceed simultaneously and in the exploration, recording, sampling and testing of materials available, once the preliminary stages of design have been passed, much of the detailed work is directed toward control during construction.

If the materials are such as to lead to a homogeneous type of dam, field procedure may be comparatively simple. In the general case of a design calling for several zones and using several grades of materials, however, it is essential that the exploration be sufficiently widespread and sufficiently detailed to map in three dimensions, i.e., to the full depth economically workable, as well as in area, every substantial significant variation in the materials which occurs, and to do it in such a manner that the quantity of each grade available in each place may be determined. To do this it is necessary to sink pits on a surveyed grid-system, at spacings which depend on the variations encountered, but which should be at least as close as a few hundred feet. Auger bores may be used to supplement the information from pits, but, for reliable information and representative

samples, the latter are much to be preferred. The materials encountered in each pit are logged, and sufficient samples taken to establish the extent and depth of each grade.

The samples so obtained provide the special information required for design. They are also classified by inspection, mechanical analysis, moisture density and penetration resistance and records are made in such a form that, during construction, it is possible to define, within approximate limits, the areas and depths at which the materials required for the several zones are to be obtained.

Control in the Borrow Pit

Control of moisture of the fill material is more conveniently effected in the pit than on the bank, as the moisture can be applied there in such manner and at such a time as to permit of fairly uniform distribution, which is improved by subsequent mixing in the process of excavation and handling. The usual procedure is to measure the field moisture content by sampling at several depths, either by pits sunk just ahead of excavation (original exploratory pits are of no use for this purpose) or by bores. At Long Valley Dam a special power-driven auger was in use. From knowledge of the materials within a given section and their actual moisture contents the water to be added is computed. This is distributed by reticulation pipes of special light construction with a rubber-packed toggle-type of joint and uniform distribution of the correct quantity is ensured by the use of gaging tins placed at frequent intervals. If overwatering occurs at any point, the sprays at that point are regulated.

Control on the Bank

Materials are delivered to the bank—in trucks or scoops, spread in heaps or rows, leveled, watered if necessary and rolled. To ensure that the several materials are put in their correct places, and that following treatment they will have the intended density and moisture content, however, the operations must be controlled by constant inspection, test and, if necessary, correction.

1. Moisture Content: As soon as the material has been leveled and before any rolling is done, it is tested for moisture content. The usual procedure is to make from it a series of samples for needle tests, some from the bottom layer and some from the top. The material is compacted in small aluminum cylinders in the standard manner and, from the observed needle readings, the moisture content is deduced by reference to a table supplied from the field laboratory. If the tests of the soil as delivered fall within the required range, rolling is commenced. If not, the soil is either watered or scarified and allowed to dry, after which the tests are

repeated. If the deficit (or excess) of moisture is due to conditions in the pit, these may be corrected or the excavator moved.

2. Consolidation: After rolling, and before placing of the next layer, check tests are made. An area is cleared down to the compacted layer and several needle tests are made in the consolidated material. The material is then dug out, and needle cylinders made of it on the spot. These two sets of needle readings should be consistent and within the allowable range. Similar tests are made at selected points, about 50 ft. or so apart, and at points where the effectiveness of consolidation is in doubt. If the readings in these or other check tests are low, more rolling may be ordered, or moisture correction may be applied.

3. Field Density: A further check-test is that of field density and moisture. At a prepared point material is dug out of the consolidated layer and the volume of the hole is determined by filling it with great care with dry sand, or with water enclosed in a bag of fine dental rubber. The material removed from the hole is taken to the laboratory and carefully weighed and the density in place deduced. Part of the sample is dried out in an oven to check the moisture content and the remainder is divided into 7 parts and moistened to give seven different moisture contents. Of each of these the compacted density and penetration resistance are measured and recorded graphically. These curves form the basis of the table supplied from the laboratory to the bank supervisor from which the latter is able to determine from needle readings whether more moisture or less is required and approximately how much. On some works, one such test is done for each 2,000 to 3,000 cu.yd. in place; on others three, or five or more tests are made per day. By this means, the basis of moisture control is subject to constant readjustment, and is thus independent of the unavoidable variations in the nature of the soil from point to point in the pits.

4. Marking and Checking: Effective control on the bank usually involves marking out in some clear manner, as with stakes, the sections under test, those in which spreading is being done, and those being rolled. It involves also checking the thickness of layers before and after rolling, recording the roller passes over each section, and the checking of coverage to ensure that all sections are adequately rolled.

For record, during construction, regular percolation tests are usually made of samples taken at predetermined points within the fill using normal loads equivalent to the weight of bank at the point, and actual observed moisture and density.

Plant and Methods of Construction

It is probably true that the most important phase of the whole construction program is that of designing the layout of the works and selecting

TABLE 1

NAME OF DAM	QUANTITY (APPROX.) CU.YD. EARTH AND ROCK	LEAD (SINGLE)	EXCAVATORS	TRANSPORT	ROLLERS
Cajalco	3,250,000	>3,000 ft.	4 No. 2½-cu.yd. Shovels	10-cu.yd. Trucks	Caterpillar Tractors, drawing Sheepsfoot Rollers
Deer Creek	2,700,000	2,000 ft. increasing	3 No. 2½-cu.yd. Shovels 1 La Tourneau Unit	13-cu.yd. Euclids 15-cu.yd. Trucks	D.8. Caterpillars drawing Sheepsfoot Rollers
Denison	18,000,000	Short	Le Tourneau Units filled and drawn by D.8.Caterpillar Tractor		
Franklin Falls	2,600,000	2,000 ft. to 4,000 ft.	8 No. 1½-cu.yd. Shovels or Draglines	13-cu.yd. Euclids 13-cu.yd. Oshkosh 5-and 10-cu.yd. Athey Wagons drawn by Tractors	D.8. and Allis Chalmers Tractors drawing Sheepsfoot Rollers
	300,000	3 mi.	Shovels	6-cu.yd. Trucks	
Green Mountain	4,500,000	2,000 ft.	4-cu.yd. Shovels (Material too bouldery for scrapers)	24-cu.yd. Trucks	Cletrac and Caterpillar Tractors drawing Sheepsfoot Rollers
Hansen	14,000,000	2,000 ft. to 6,000 ft.	4-cu.yd. Shovels and Draglines	24-cu.yd. Trucks	D.8. Caterpillar Tractor drawing Sheepsfoot Rollers
			23-cu.yd. Le Tourneau Scrapers drawn by Tournapull units, filled by D.8. Caterpillar Tractors		
Lackawack	8,000,000	3,000 ft. to 6,000 ft.	Initial stages 2-cu.yd. Shovels	Athey Wagons drawn by D.8. Caterpillar Tractors	D.8. Caterpillar Tractors drawing Sheepsfoot Rollers

Long Valley	1,000,000	2½ miles	2½-cu.yd. Shovels	13-cu.yd. Euclid Wagon 12-cu.yd. Trucks	D.8. Caterpillar Tractors drawing Sheepsfoot Rollers
Prado	3,200,000	2,000 ft. to 5,000 ft.	Scraper Equipment		Sheepsfoot Rollers
San Fernando	500,000	2,000 ft.	23-cu.yd. Le Tourneau Units drawn by D.8. Caterpillar Tractors and filled by similar tractor pushing 12-cu.yd. Garwood Scraper Units similarly pulled and filled.		D.8. Caterpillar drawing Sheepsfoot Rollers
Sepulveda	4,000,000	2,700 ft.	Elevating Grader	13-cu.yd. Euclids	D.8. Caterpillars drawing Sheepsfoot Rollers
Tionesta	2,000,000	2,000 ft.	10-cu.yd. Le Tourneau Units drawn by D.8. Caterpillars		
			2- and 2½-cu.yd. Shovels	13-cu.yd. Euclids Athey Wagons	D.8. Caterpillars drawing Sheepsfoot Rollers
Vallecito	5,300,000	3,000 ft. to 5,000 ft.	Le Tourneau Scrapers drawn by Tractors when pits were close		
			2½-cu.yd. Shovels or Draglines	13-cu.yd. and 18-cu.yd. Euclids 14-cu.yd. Trucks	D.8. Caterpillars drawing Sheepsfoot Rollers

the plant to be employed. This has a decisive effect on the cost of the work and may fundamentally affect its quality.

In earth-dam practice, there is considerable flexibility in relation to the materials which can be used, and as stated earlier it is generally true that the design can be made suitable for the use of the materials adjacent to the site. It is, in consequence usual to find that most of the materials for earth dams are transported no further than a few thousand feet.

Modern earth moving plant has as its chief function one or both of the operations of digging and transporting. Independent digging is effected by heavy powerful units such as shovels and draglines; and independent transporting is done at high speeds in units such as motor trucks or railway trucks. Combinations of units have been developed in recent years to perform both functions.

There are three general methods of operation:

1. Scrapers on pneumatic tires and tractors on caterpillar tracks—a self-contained combination, performing all functions of digging, transporting and spreading, but slow moving (speeds ranging from 2 to 6 mph.) and limited in usual application to leads up to about 2,000 ft.

2. Scrapers and tractors on pneumatic tires—requiring the assistance of tractors on caterpillar tracks for filling; these are fast moving (10 to 15 mph. loaded, 20 to 25 mph. empty) and self-spreading, and in usual application they are operated on leads up to 4,000 to 6,000 ft.

3. Excavators and trucks, or excavators and truck-trailer units—this transport is fast moving (15 to 35 mph.), but trucks and wagons dump in heaps and thus make the provision of spreading plant necessary. In dam practice, this type of equipment is still the commonest on moderate and long leads.

Manufactures of plant of the kind in method 2 claim that it is as suitable for all leads as are trucks, and is more economical. The practice at present, nevertheless, is as above. At Hansen Dam (see Table 1) high speed scraper-tractor units (method 2) were used on leads of 3,000 to 4,000 ft., and 24-cu.yd. motor trucks filled by 4-cu.yd. excavators on longer leads. At Franklin Falls Dam, 300,000 cu.yd. of impervious core material is being transported 3 mi. in 6-cu.yd. trucks, shovel loaded. At Long Valley Dam, where the lead is $2\frac{1}{2}$ mi., 13-cu.yd. Euclid wagons and 12-cu.yd. trucks are being loaded by shovel.

For very high rates of construction and the moving of large total quantities on leads of, say, 4 or 5 mi. or more, the method of railway transport, now superseded on short leads, should not be overlooked, particularly if wet conditions may cause special difficulty with trucks to and on the embankments.

4. Structures of Concrete

Requirements of Good Concrete

In their most general form the requirements of concrete are: uniformity, strength, durability and economy.

Owing to the inherent limitations of the material, it is by no means easy to ensure these qualities. Of recent years, some control of these limitations has been achieved—in the first place, in the laboratories, where a better understanding of the materials has been reached (as for instance in the relation of water and cement to strength, shrinkage, watertightness and durability) and where special materials have been developed (special cements and jointing materials); secondly, in the designing office, where form has been given to the structure such that the limitations of the material are provided against (as in the provision of means to control cracking, and to grout the structure, after shrinkage has ceased, to a single structure unit); and thirdly, in the field, where by the use of suitable aggregates and proper methods of proportioning, handling, and treatment, a material has been produced which in the broad sense of the above requirements, is good concrete.

To ensure durability, the concrete must be watertight. It must accordingly be free from cracking, and at the same time impermeable throughout its mass, as the passage of water through it quickly breaks down its structure. For the concrete to be impermeable the mix must be well graded to produce maximum density and should be free of excess water, which gives rise to water voids; it must be uniform, workable with the equipment to be used (e.g., vibrators) and properly compacted into position. The heat evolved must be as little as possible, and the volume change with variation of temperature and moisture a minimum. This calls not only for special cement (see below), but also for the use of the least possible amount of cement, and the least possible amount of water per unit volume of concrete.

Loads

In American practice, in addition to dead load and water and other live loads, provision is usually made for earthquake forces, and sometimes for ice loading. Earthquake accelerations are usually computed as one-tenth of gravity, with a period of one second. Owing to the temporary nature of earthquake stresses, higher working stresses are adopted (for instance compressive stress may be allowed at 900 to 1,000 psi.).

For uplift—i.e., the upward water pressure applied to the base of the structure, or applied between faces at a joint or crack within the structure—it is usual in the Bureau of Reclamation to compute the pressure as varying

linearly from full head water to full tail water, but acting over only two thirds of the base.

Structural Analysis

In the recent developments of structural analysis, and more particularly in that of large concrete dams, there has been close association between studies of models, computation, and the direct measurement of strain, stress, and deflection in actual structures under load.

There are in general three systems of stress by which the loads on a dam may be transferred to the supporting formation:

1. By cantilever action from the base
2. By arch or beam action from the abutments
3. By twist action.

The proportions in which the applied loads are in any given instance shared between the three systems will in general depend on the relative rigidities of the systems. This is the underlying principle of the trial load method of analysis in which it is assumed that the load is distributed between the systems in such a manner that at every point in the structure the deflections of the different systems are equal.

The trial load method provides a comprehensive picture of the state of stress, and one which is more closely in conformity with the results of direct observation than that provided by the older methods, which involved simplifying (and inaccurate) assumptions such as those that in an arched dam the whole load is taken by horizontal arch action, or in a gravity dam, by vertical cantilever action.

Stress

The stresses to which foundations and abutments may be loaded are usually the subject of careful investigation as described earlier. This has been more necessary in recent years in connection with the exceptionally high structures which have been built, in the foundations of which very high stresses have been allowed.

The stress for which concrete is designed depends to some extent on its duty, but in general it is required to reach 3,000 psi. at 28 days.

1. Measuring Stress: The elastic constants and the condition of internal stress within a loaded mass of concrete depend to a great degree upon such indeterminate factors as the effect of the proportions of the mix, and of curing, and the plastic deformation with age. At an external surface, stress may be deduced from measurements of strain (provided the elastic constants are known); but internal stress is not so easily determined. It is common practice in large mass structures to use the Carlson Strain Gage which provides an accurate measure of both temperature and strain.

As the instrument is uni-directional, it is necessary to imbed six gages to evaluate three-dimensional stress at any one point. In the installation at Shasta Dam, to provide for checking and for the separate evaluation of strains due to temperature, moisture change, etc., it is proposed to imbed twenty gages at each point, the gages being assembled in clusters for convenience in setting.

2. Concrete in Tension: One of the most important limitations of concrete as a material for carrying stress is its low tensile strength. This has in the past resulted in objectionable and sometimes dangerous cracking. By admission of water, and by permitting the passage of water under pressure through the material, cracks also lead, in hydraulic structures, to deterioration and loss of durability.

When concrete is setting, heat is evolved as a result of the chemical action of hydration of the cement. If the heat is not dissipated, the temperature rises. The concrete sets in an expanded condition, and when later the temperature falls to air or water temperature, cracking in tension may follow, if movement is prevented or restrained.

Many of the important developments of modern concrete practice relate to methods for the control or prevention of cracking.

Control of Cracking

Cracking of concrete may result from rise in temperature during setting, as described above, or from subsequent variations in temperature or in moisture content. It may be controlled in one or more of several ways:

1. Tension may be decreased by limiting the rise in temperature, either by decreasing the heat evolved by the use of special cements and the use of the least possible amount of cement or by removing the heat evolved by means of natural and artificial cooling.

2. Restraint may be eliminated by the provision of suitable free joints. If permanent, these joints must be made watertight by incorporation of some type of flexible water stop. If temporary, provision must be made to close or seal them when the temperature has fallen to its permanent value.

3. Tension may be decreased by utilizing the property of concrete whereby it swells when moist. Moist curing for some time after setting limits the shrinkage until the tensile and bond strength of the concrete have developed.

4. Tension may be resisted by the provision of adequate reinforcement.

1. Special Cements: Most of the heat evolved during the setting of cement has been found to arise from the hydration of certain compounds, and satisfactory cements have been produced which contain less of these. Two such are low heat cement and modified portland cement.

a. Low Heat. Low heat cement has a total heat evolution of 20 per cent less than standard; but, more important, its rate of evolution of heat in the early stages of setting is about half that of standard cement. Hence the cooling devices used, such as circulation of cold water, have time to take effect, and the temperature of the mass is kept at a much lower level. One economic defect of this cement is its much slower hardening, which requires leaving forms in place longer. In large massive structures, where natural cooling would be small and in which, without special provisions, temperature rise would be very great, low heat cement is regularly used, in conjunction with cooling by circulating water and other methods of controlling the temperature gradient within the mass.

b. Modified Portland. For less massive and less important structures, a cement has been sought which would not involve the same economic objections, but would still give less heat evolution than standard cement. For this purpose, modified portland cement has been produced. It has the same early hardening characteristics as standard cement, but a total evolution of heat intermediate between that of "standard" and "low heat," and, even without artificial cooling and other special methods, has given very good control of cracking. This cement has almost wholly replaced standard cement for ordinary use in water structures in America.

2. Cooling and Block-Grouting of Mass Concrete: Removal of heat from massive structures, whether constructed of low heat cement or of modified cement, is standard practice in the construction of large dams. In an attempt to ensure that such a structure will finally become a homogeneous monolith and not a mere aggregation of blocks of irregular size and shape produced by uncontrolled cracking, there are provided in the design, construction joints which are free to open as shrinkage takes place and which on the completion of shrinkage are grouted tight with cement grout. The spacing of joints is proportioned by consideration of the expected rise in temperature (in view of the cooling to be provided) to ensure not only that no cracks form between joints, but also that the joint opening, when the temperature of the mass has fallen to its permanent level, will be not less than 0.02 in., which is the opening necessary for effective grouting.

3. Permanent Flexible Joints: In structures of which the effective functioning does not depend on monolithic behavior, or where a small degree of independent movement between sections may prove of advantage in the permanent working of the unit, (in contrast to the temporary need of flexibility during cooling) permanent flexible watertight points are commonly provided. Older types of joint are the Z and U copper waterstops. For places from which light and oil can be excluded, rubber has replaced metal to a considerable extent.

Fineness of Cement

The fineness of grinding of cement has been found to have an important effect on the behavior of concrete in the early stages of setting. Finer grinding results in higher early strength and more rapid evolution of heat, but nevertheless it is now common practice to specify a minimum fineness, as it has been found that on the very much greater surface area of the particles of a finely ground cement the water is more effectively retained, and there is less tendency to "bleeding" and "sand streaking"—particularly in dry mixes placed by vibration.

Sieving is not effective in separating into fractions the sizes finer than 200 meshes to the inch, and water-sorting has been adopted (as in the various types of turbidimeter). By means of this the specific surface—in square centimeters per gram of cement—is determined. Below 1,600 sq.cm. per g. there is separation of water and loss of workability. It is generally required by the Bureau of Reclamation that specific surface exceed 1,800 sq.cm. per g.

Proportioning

It has been seen that the cement requirements for strength (the greatest possible amount of cement) are in conflict, as are to some extent the water requirements for strength (the lowest possible water-cement ratio—i.e., a dry mix) and for durability (sufficient water to produce a plastic workable mix). The actual design of the mix is a compromise in which, in general, the lowest possible values of both water and cement content are sought.

The problem of proportioning is that of producing from the available aggregates a concrete of the required strength which will contain the least possible amounts of water and cement and which will be sufficiently workable to be properly placed in the positions required by the plans.

The best combination of the several sizes of aggregate for density and workability is usually determined by trial mixes or from experience. In general the lowest possible proportion of fine aggregate is sought. A suitable water-cement ratio and a suitable consistency (slump) having been selected, the actual mix which satisfies these requirements is determined by trial.

The water-cement ratio is selected in consideration of the strength required. For ordinary work, with gravel aggregates, a ratio of 0.6 by weight is a usual figure; for masswork up to 0.65; and for highly stressed reinforced work as low as 0.5 to 0.55.

The slump to be used should be no more than sufficient to ensure proper placing. For placing in heavily reinforced sections and confined spaces,

slumps of 3 to 4 in. are required if vibration is to be used. In open forms, in mass concrete, the slump may be as low as 1 to 2 in.

The usual practice in specifying the proportions of concrete is to state the minimum compressive stress required at 28 days, the maximum water-cement ratio, and the sizes of aggregate to be used. The actual quantities of cement, water, and the several sizes of aggregate are then determined from time to time by the construction officer.

The quantity of cement to be used is generally expressed as the weight of cement, or as the number of packages of standard weight (bags or casks) per cubic yard of concrete in place. Proportions of 4 bags of 94 lb. each per cubic yard for mass concrete, rising to 6 bags per cubic yard for highly stressed reinforced concrete, are typical of American practice.

Aggregates

Crushed rock aggregates are widely used for ordinary concrete work, and have been used in recent major hydraulic structures, as at the Norris Dam and Hiwassee Dam of the Tennessee Valley Authority; but it is generally recognized that natural aggregates permit of the use of less water for equal workability, and hence lead to economy and durability. In most of the recent projects involving large concrete dams, as at Boulder, Grand Coulee, Shasta and Friant, it has been possible to obtain pit or river gravel, and there has resulted remarkable development in the methods of processing, designed to produce from the variable natural deposits of the different grades of aggregates in the proportions required for the work.

As might be expected, the proportion of sizes in the pit is seldom the proportion required for the concrete, and, even where on the average it is nearly so, wide variations occur from place to place in most pits, and of course there are usually variations from time to time in the mix in use in the structure.

Thus, one of the problems of aggregate processing is to fit the varying grading of the raw material to the different and varying grading required for the manufactured product. As every yard of pit gravel excavated must be at least partly processed, it is clear that the less of it wasted in keeping the output to the correct proportions the better.

Aggregates on major works are excavated by dragline shovel, or scoop, but in almost all instances they are transported between pit, processing plant and works on rubber covered conveyor belts. At Shasta the main conveyor between the pit and the works is 36 in. wide, 9½ mi. long, with a capacity of 1,100 tons per hour. The great advantages of capacity and simplicity of loading and unloading have established conveyors firmly for this class of work. The usual method of feeding the conveyor is to lay it in a tunnel under the stock pile, and feed through a remotely controlled shaker or vibratory gate set over the belt. At the discharge end of con-

veyors, coarse aggregates are not dropped on to the stock pile; they are lowered on ladders which consist of a flight of short zig-zag chutes, down which the material slides with short drops, thereby preventing breakage and segregation.

Cement

Cement is usually delivered to large works in bulk in special box cars. From these it is pumped to storage silos. The pump is a blower, mounted on a pneumatic tired frame. The unit propels itself about in the car by a motor under the remote control of a "mercoid" switch held in the hand of the operator, who remains outside. From the silos cement is discharged by screw conveyors to blowers working at low pressure, or to intermittent air-pressure ejectors working at about 100 psi., and is blown or forced through iron pipes to the mixing plant—at Grand Coulee Dam, 6,000 ft. away.

Mixing

Mixing of concrete on large works is carried out in central plants which have been developed to a more or less standard pattern.

Aggregates and cement are fed into bins at the top of the building, the feeders and belts which draw aggregates from their respective stock piles being remotely controlled by the attendant at the bins. From the bins the materials pass to weighing batchers (one for each bin) and thence to a central charging hopper which has a rotary discharging chute. As a mixer is to be charged the chute is swung round to register with the mixer inlet.

In the Johnson equipment, which is in use on many of the large concrete dams, every operation from the charging of the batchers is under remote control, and automatically interlocked with the other operations to ensure proper sequence. The batchers can be set at the control panel to produce without delay any one of the great variety of allowable mixes. When the weight of material in the batcher is close to the correct figure, the door is almost closed and is given a shaking movement. The resulting trickle of material permits fine adjustment in the weight of the batch. The weight of every batch is recorded electrically on a master chart in the control room. In this type of equipment, tilting mixers are generally used, as less headroom is required with them, and it is claimed their mixing efficiency is greater.

Handling

One of the important problems in handling the mixed concrete is the prevention of segregation. One reason tilting mixers are preferred is that they dump their batch bodily instead of running it out. At the

discharge chute of the ordinary drum mixer segregation often occurs to such a degree that re-incorporation of the materials is never effected.

To limit segregation in transit, the ideal provision is that of agitators, as used in the transit mixer. This is commonly provided if the haul in skips is long. At drops and transfer points baffle hoppers or remixing devices are used and, in filling deep forms containing reinforcement, the concrete is directed past the bars in vertical tubes to prevent scattering of the aggregate.

Concrete sufficiently plastic or fluid to run in chutes of usual slopes and lengths must be far wetter than is allowable in good practice. It is possible by exercising extreme precautions to handle concrete in short steep chutes of wide section without separating its ingredients, but it is so difficult that the use of chuting has practically ceased.

Although the objections to handling mixed concrete by belt conveyors are not so strong, there is separation at the points where the concrete leaves the belt and falls either on another belt or into the forms, and cement and water are constantly lost to the belts and by splashing, etc. While belt transport is not usually prohibited, it is now rarely used.

There are four methods of handling in regular use:

1. Bottom dump skips of large opening are filled at the mixer, and transported to the forms by truck, cableway, or crane, or by a combination of them. The skips are lowered close to the concrete in the forms, being so designed as to empty without scattering of the contents.

2. Motor trucks or hand trucks are filled at the mixer, traveled to the placing point, and discharged into the forms. If the trucks are tipped into skips for hoisting, there is some risk of segregation.

3. Concrete materials are placed in a transit mixer at a central plant. The concrete is mixed in transit, and discharged into the forms or into skips at the concreting point.

4. Concrete is fed to a concrete pump or gun, and pumped through piping into the forms.

The great concrete structures of recent years have all been constructed by the first method, with slight modifications in some instances.

1. Pumping of Concrete: Pumping of concrete is a convenient method for placing comparatively small quantities over great lengths or areas, as the equipment is quickly and cheaply extended and with proper precautions produces a concrete of high quality. Placing by pumping is almost standard practice in tunnel lining. It was of great advantage at Lackawack Dam for concreting inside the working chambers of the core-wall caissons, as the pressure in the line could work against the compressed air pressure without use of an air-lock. At present, the maximum delivery of pumping units is 65 cu.yd. per hr. at a distance of 1,000 ft. horizontally

in a straight line, or 100 ft. vertically and 200 ft. horizontally, or intermediate combinations of horizontal and vertical distance. Bends in the line reduce the distance materially.

2. Forms: Forms for concrete are set in lifts not usually exceeding 5 ft. in height. Advantage in cooling and elimination of cracking was claimed at Hiwassee Dam as a result of using lifts of half this height. Form panels at Grand Coulee were bolted to the concrete at the foot, and braced to alignment at the top with special metal struts and ties. At Shasta and Friant, flitched or solid cantilever legs are in use, thereby freeing the concreting space of the obstruction of struts, etc. Until recently, for the best class of finish, steel forms or plywood treated with shellac have been used. With the production of dense strong vibrated concretes from mixtures of low cement and water content, the development of air bubbles and sand streaks on formed surfaces has become more general and has to a great degree destroyed the smoothness and perfection of the finish. With the best class of concrete, the more thoroughly the work of placing has been done, the more these defects have developed. Research into this matter has been carried out by the Bureau of Reclamation, and it seems likely that a solution of the problem will be found in an absorptive form lining using a board of a synthetic material such as Celotex. Such a lining absorbs the air which reaches the form face, and absorbs also some of the water which vibration liberates, thereby producing, as it were, a case-hardened concrete skin. There are problems connected with this development, but some excellent results have already been obtained in large scale tests.

3. Vibration: Vibration of concrete liberates the entrained air and produces a concrete of greater density. It enables dry mixes (which would be otherwise impossible to compact) to be worked satisfactorily, thus making it possible to manufacture stronger and more durable concrete. It is almost universal in America on works of any importance. Vibrators are usually internal, either pneumatic or electric; but external vibration is used where access is difficult for internal machines. Research is being conducted into the best frequency and amplitude for such machines. At the present, speeds in excess of 5,000 rpm. are common.

Over-vibration may give rise to segregation. It has been found better to vibrate for short periods at many points than to endeavor to work the concrete over a larger area from one point, as at the latter there is a tendency for the larger particles to sink.

Bonding of Concrete

At one time it was the practice to roughen by picking the surface of set concrete to which new concrete was to be bonded. More recently,

picking has been done away with, except in the special circumstances described below, and it has been usual to clean and roughen the concrete by scouring with a jet of water and compressed air, this being done when the surface layer was sufficiently soft to be cut without loosening the aggregate. There is some risk of permanent damage to the concrete if this method is applied too soon or with too great intensity; and, at the same time, the surface is often dirtied again by traffic, or a film of calcium carbonate forms on it by exposure, before the new concrete is placed. This renders a second cleaning necessary.

As a result of investigation, a new method is now in use by the Bureau of Reclamation. The old concrete is left in a normally rough condition—that is, no special smoothing is done—and is covered with wet sand while still fresh, to prevent the formation of a film of carbonate. When the new concrete is to be placed, the sand is removed, and the surface is scoured with a jet of compressed air and water.

Recent tests conducted at Denver indicate that, provided the concrete is good and sound right to the surface as well as free of film, the bond produced in this manner is stronger than the adjacent concrete.

Curing

This is one of the important operations in the production of good concrete. For the proper hydration of the cement, concrete must be kept moist, and the longer this condition is maintained, the more fully hydration is effected. Incomplete hydration results in decreased strength, durability and hardness.

5. Behavior of Earth and Rock Structures

With both earth and concrete structures, observation of performance is of the greatest value in checking the assumptions of design, and the adequacy of theories and computations. What is equally important, it provides the most certain and reliable means of keeping under constant supervision the functioning of the structure, and determining in advance the need for special works, or methods of operation, and the nature and extent of maintenance works which should be undertaken.

Settlement

As the fill rises, more and more load is imposed on the lower layers, causing consolidation and shrinkage. Poorly compacted embankments undergo a considerable decrease in volume, which continues long after construction has been completed. Embankments in which there have been effective control of moisture and thorough consolidation have been found to subside as much as 4 to 8 per cent, depending on the depth of the

fill; but the greater part of this has been found to occur before construction has been completed. Not only is this shrinkage of importance in regard to structures, such as parapet walls, operating buildings, etc., which must be constructed on the fill, but also it is closely associated with the rise of pore pressure within the structure.

The extent to which reliance is placed on effective consolidation of earthworks by the use of suitable methods and equipment is noteworthy. It is not uncommon practice to construct important concrete structures on newly built embankments—as, for instance, was successfully done at the University Mound Service Reservoir at San Francisco, where a concrete lined and concrete roofed structure was built on a cut and fill foundation, where the depth of fill approached 50 ft. A similar instance is the construction of a continuous concrete facing slab on an earth dam, as was done with success at Bouquet Canyon and Cajalco Dams. After some years of service, the measured subsidence of these slabs is very slight, and little or no cracking is visible.

Pore Pressure

As already described, in certain classes of material the moisture which is present in the pores or between the grains cannot escape readily when pressure is applied. During construction, consolidation sets up pressure in this moisture, and this pressure is increased as more and more fill is superimposed. It is possible with impervious materials for pore pressure to become very high and to decrease substantially the stability of the structure even before any water is stored against it. Pervious materials drain readily and do not lose stability to the same degree. It is of importance during and after construction to observe pore pressures, and for that purpose piezometer tips are imbedded at selected points in the material of the fill and connected by copper piping to suitable pressure gaging equipment.

Percolation

The passage of water through the dam is not necessarily a defect; in fact, it is provided for in the designs of some structures. It should not, of course, be of sufficient velocity or concentration to move the particles of the fill, and the drainage of the downstream part of the fill should be adequate to maintain stability. In most conservation dams, and particularly those storing water for city supplies, an effort is made to reduce seepage to a very small quantity.

In order to keep the behavior of the structure under constant observation, it has sometimes been arranged to lead all leakage water to a gaging chamber, and to record the flow automatically. It is important

to ascertain whether the observed flow varies with the depth of water stored (indicating leakage through the structure) or with rainfall (indicating soakage and drainage from the bank and the side hills); in the former instance, it is important to ascertain whether, other things being equal, there is general increase or decrease with time.

Weight of Fill

If at any point in the mass of the fill there is differential settlement, pressure due to the weight of fill may be less at that point and greater at some points remote from it. Such variations in pressure would be useful indication of internal conditions. Steps are in hand in America to devise a reliable electrical means of measuring the pressure at any prepared point within the fill, both before and after filling of the reservoir.

6. Performance of Concrete Structures

In most recently constructed masonry dams provision has been made to measure performance in operation in regard to stress and strain (already described), deflection, cracking, uplift, leakage, and internal temperature. Measurement of the total quantity of lime in the leakage water has been undertaken as an indication of the deterioration of concrete in the structure and of grout in the foundations.

7. Spillways and Crest Gates

Determination of the necessary spillway capacity and the provision for it in the design are major problems in connection with hydraulic structures. Mention is made later of American practice in estimating peak floods, and in deriving from them the spillway-design floods.

In general, spillway practice depends both on the type of dam and on local conditions, such as the occurrence of rock at the site, the possibility of damage or blockage by floating logs or ice, the use of the structure and method of operating it. Practice, however, also depends on the type of project. With conservation projects, the reservoirs are often full, and spillways operate frequently, whereas the objective in operating flood control projects is to keep the level of the reservoir as low as possible (with certain restrictions as to minimum levels in some instances) for as long as possible. In this type of project, spillways operate very rarely, and outlet works, usually at or near low water level, operate regularly. Unlike the outlet works of conservation dams, those of flood control dams are usually continually accessible for maintenance. They are designed, just as spillways are, to control peak floods and, with the assistance of reservoir storage, to pass flood waters at a predetermined rate. They are, in fact, in most essential respects the spillways of the dams.

The Intake Structure

1. The Uncontrolled Weir: This is the simplest form of spillway intake. It consists of a weir of sufficient length to pass the spillway flood with a safe rise in reservoir level. This type of structure is comparatively common in conjunction with earth dams, but less so with masonry structures, on which it is common practice to install crest gates.

2. Gate Control: The economy of the use of crest gates in increasing storage without increase in the height of the dam needs no emphasis. They may be operated either automatically or manually to maintain a practically constant reservoir level at all stages of intake; but the common objection raised against their use is that neither method of operation is completely reliable. In the recent practice of the Bureau of Reclamation, however, many such dams have been fitted with gates, where it has been possible to ensure skilled operation and maintenance. The Bureau practice has not been followed by other water supply authorities or to any great extent by the U.S. Army Engineers.

The common types of crest gates are:

1. Radial or tainter gates
2. Drum gates
3. Bulkhead gates—stony type
4. Roller or cylinder gates
5. Ring gates.

a. Radial gates are probably the most frequently used of all the types. They have the advantage of relatively low cost. They possess a degree of flexibility, being supported on radial structural steel arms rotating on pins, and accomodate themselves readily to slight relative movements of the supporting piers. The larger gates are usually counterweighted and the lifting effort is small. Radial gates are not suitable where ice or logs may strike them as they are easily unseated, or for long spans (for which drum and roller gates are used) or for exceptional depths (for which bulkhead gates are used.) A large gate of this type is that used at Caballo—50 ft. long and 21 ft. high. Gates as long as 80 ft. are to be installed on one of the Mississippi navigation control weirs by the U.S. Army Engineers.

b. Drum gates are rigid and require careful setting on any unyielding foundation. The type is suitable for long openings, as it is hinged at intervals across the opening, instead of at the ends only. It is robust and provides a large clear opening suitable to pass ice or débris. The drum gate is costly to make and install and as it requires a large chamber below crest level it is rather unsuitable for weirs and spillways where the depth

from crest to rock is not great. It finds its commonest use in the overfall crests of large masonry structures. The length of drum gates is limited only by the amount of expansion and contraction to be provided for. Gates 135 ft. long and 28 ft. high will be used at Grand Coulee dam, but much greater lengths are contemplated.

c. Bulkhead gates or flat gates are modified stony gates. They move in vertical slots on rollers or on caterpillars, and are the most suitable for narrow openings where more than 20 ft. in depth is required. Gates of this type require unyielding foundations. They are costly, but nevertheless are widely used where conditions are suitable.

d. Roller or cylinder gates are the heaviest of all gates. They are operated by gearing on one end, which therefore must be heavily and rigidly constructed on an unyielding base. They can be made overshot or undershot, and may be built to lengths exceeding 100 ft. and to 14 ft. in diameter. As the provisions at the operating pier, and the pier itself, are very costly, wide spacing of piers and long gates are economically necessary. This type of gate is one of the best where ice or débris is to be expected, and is commonest in the low diversion weirs of irrigation projects.

e. Ring gates have occasionally been used, as in the control towers of Boulder Dam or the intake to the circular shaft spillway at Owyhee Dam.

The ring gate at Owyhee Dam is in effect an annular drum gate, of approximately rectangular cross-section. It floats in a chamber, circular in plan, formed in the lip of the circular intake weir. The whole gate lifts and retracts vertically (in contrast with the rotary movement of the drum gate), being operated by the buoyancy of the water admitted into the chamber from the reservoir. Automatic control is provided by an arrangement using a float and needle valves, similar to that used for the control of straight drum gates.

3. Siphon Control: Siphon spillways and wasteways are commonly used for the regulation of channels and minor structures. Their use for major structures such as dams is rare. They suffer from one outstanding defect in comparison with uncontrolled-weir spillways, that with increase of head beyond that at which the siphons are fully "primed" there is little increase in discharge. Hence the safety provided by such a spillway against a flood in excess of that for which the structure was designed is comparatively small.

The Channel

The simplest form of spillway channel is an unlined or partly lined rock-cut, in which the water flows at comparatively low velocity, or drops in falls and rapids, to the stream bed. Where such favorable conditions are not available, as at many earth dams and some concrete dams, the spillway channel is usually either a chute or a tunnel.

1. Chute Spillways: Chute spillways have concrete lined channels with vertical sides and very steep grades. The chute is usually founded on solid natural formation, clear of the embankment, although one of its side walls may act as a retaining wall for the earth-fill.

2. Tunnel Spillways: Tunnel spillways are usually driven in solid formation to one side or under one shoulder of the dam, the tunnel driven to carry the stream past the site during construction being sometimes utilized. The tunnel method is particularly attractive when the rock at low levels is sounder and harder than that near the surface.

The Stilling Structure

At the outlet where the spillway discharges into the stream, it is sometimes unnecessary to make special provisions against scour and erosion. This is the case with the discharge from the chute spillway of Green Mountain Dam, where the outlet of the chute is in solid rock. At the outlets of the crest-spillways of flood-control dams no provision is usually made because it is held that, as the spillways operate so seldom, it is cheaper to repair the damage which may result than to endeavor to prevent it. But in general, it is necessary to provide a more or less elaborate structure to dissipate the energy of discharge before the water is permitted to enter the natural watercourse. Some mention of the various methods in common use has been given under the discussion of model analysis, which is the ultimate basis of design of all such structures. These methods are:

1. Simple stilling by discharge into a large deep pool of water
2. Formation of a hydraulic jump, with or without end sills and baffles
3. Throwing the water up on a trajectory from a bucket
4. Dissipation of energy in a diffusion bucket.

The stilling pool is an effective device to which the only objection is the very great size and cost of the pool necessary to make a sufficient reduction in the energy of a large discharge.

8. Valves or Gates

The chief factors which determine the choice of the type of valve or gate to be used in connection with outlet works are the pressure under which the valve will operate and duty required of it.

Pressure

The valves used in outlet works for operation under low pressures, that is, pressures less than about 75 psi., depart little in essential respects from standard practice. Manual, hydraulic and electric operation are used, and for valves of small or moderate size bronze seatings bear on bronze faces.

Under high pressure, these types are unsuitable owing to higher velocities causing turbulence, and to difficulties such as the excessive power which would be necessary for their operation, and the limitations of their sealing arrangements.

These considerations have lead to the development of special types of high-pressure gate to meet the requirements of operation, regulation, and emergency duty. Much of the development has been made by the Bureau of Reclamation in connection with the very high structures built in recent years.

Duty

1. Emergency Duty: Emergency duty involves operation only at infrequent intervals. It usually arises in connection with adjustments or repairs to the operating gates, which are placed downstream of the emergency gate, and can be used to equalize the pressure when the latter is operated. Thus the emergency gate is not usually operated under high head, or at partial opening. The smaller gates used for this duty are often of the simple bronze-seating type, but the slide is extended below the bulkhead to form a leaf or follower in which there is an opening to match the openings in the body, thereby forming a smooth bore through the gate and eliminating the eddying which is otherwise set up. This type is known as a ring follower gate, but the same principle is used for gates with square openings.

The coaster gate is a type of emergency gate used in certain circumstances on the upstream face of a dam to close an outlet opening. The large gates used in recent designs travel on caterpillars and have hydraulic seals worked on the ring seal gate.

2. Operating Duty: Operating duty involves frequent opening and closing under full pressure. To reduce the operating effort, rollers or caterpillars are provided, but the simple methods of sealing used with low pressure roller gates are inadequate.

In the paradox gate, the slide travels on a train of rollers extending the full length of the bulkhead and ring follower on each side. In large gates the rollers are about 5 in. in diameter and roll on the gate body. When the slide reaches the closed position, a wedge system in the caterpillar assembly engages a shoulder in the body. The assembly moves for a length of 12 in. after the travel of the slide has ceased, thereby causing withdrawal of the wedge, and allowing the bronze seatings of the slide to make tight contact with the bronze faces on the body. On opening, the initial operation is to wedge the slide off the seat before movement of the slide on the rollers takes place. This type of gate is usually operated

electrically through twin motors and spindles. It is reliable and satisfactory in operation, but owing to its complicated mechanism is very costly.

The ring seal gate has been devised to meet the same conditions of use at less cost. As full pressure is never applied to the "follower" extension, this section of the slide is carried on wheels, the roller train extending only for the length of the bulkhead.

3. Regulating Duty: Regulation is commonly effected by needle valves. Under the high velocities encountered in modern structures, needle valves have suffered to a considerable degree from cavitation, and have in some instances required constant maintenance. Although the valves at Boulder Dam, for instance, have been in operation for a comparatively short time, some of the needles are already under repair. As a result of investigation and model studies, referred to earlier, new principles of design have been formulated and new designs developed.

9. Outlet Structures

Outlets From Concrete Dams

Outlets are in general of three kinds, namely, flood discharge outlets, power outlets, and outlets to conduits for irrigation or water supply. Typical arrangements of these are shown in Fig. 3. Adequate trash racks and gates are provided to protect the entry ends of these conduits. For orifices under low heads, simple slide gates are used, but for high heads, coaster gates are provided. It is frequently necessary to place flood outlets in the spillway section, where it is not possible to operate the coaster or other entry gate from the crest, or to place control valves at the downstream face.

Delivery to irrigation or other conduits is commonly regulated by needle valves discharging into a stilling pool, from which water may flow direct to a channel or to pipes, or may pass down the natural stream bed to a diversion structure.

It is sometimes convenient to arrange the outlet works of a concrete dam in a tunnel, as was done at Boulder Dam. There the space at the back of the dam was taken up by the power plant and both spillways and outlets were carried around the structure in tunnels. In such instances the arrangements used are those commonly adopted in earth-dam practice (see below), namely, the tunnel and plug or tower and tunnel. Both of these are used at Boulder Dam.

Outlets From Earth Dams

Whereas outlet conduits are commonly taken through the body of a concrete dam, it is rare for this to be done with an earth dam, where there is a real danger of rupture as a result of settlement. The usual

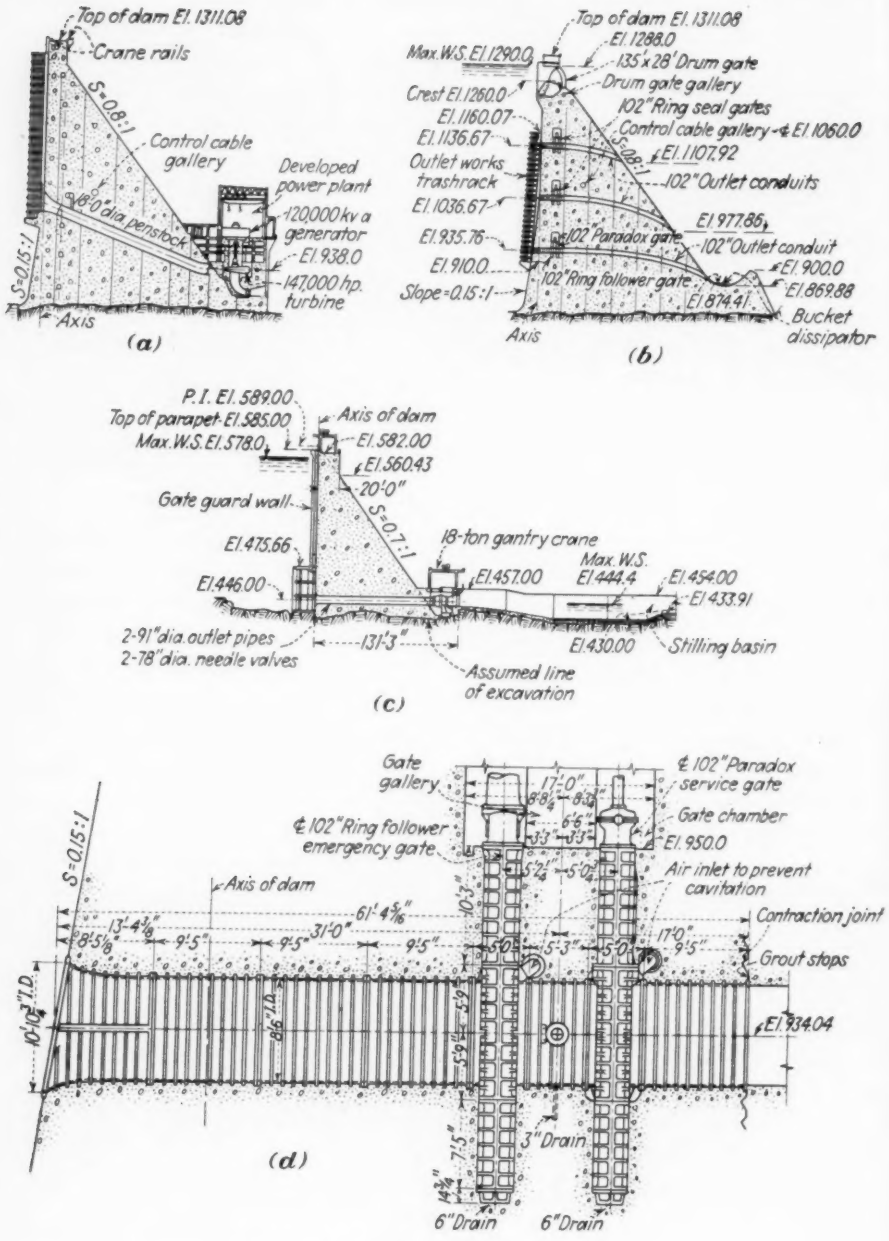


FIG. 3. Outlets From Concrete Dams

practice is to carry the outlets in a tunnel either under the dam, or remote from it, in solid formation. There are two typical general arrangements of these works—that for flood control, power, or irrigation, where usually water is to be drawn from the reservoir at one level only at or near the bottom and that used in water supply works, where it is standard practice in important reservoirs to provide for withdrawal at several levels.

Water supply outlets in which water is drawn from one level only are in general similar to irrigation outlets. The provision to draw water from any of several levels is of advantage in ensuring that, in the event of an outbreak of algae, or the occurrence of high turbidity due, for instance, to flood conditions, water may be drawn from the level least affected. The control structure for an arrangement of this kind is a tower placed at the upstream end of the outlet conduit. The latter may be a dry tunnel or culvert with either a free discharge or a controlled discharge at the delivery end. The dry tunnel has the advantage of access for

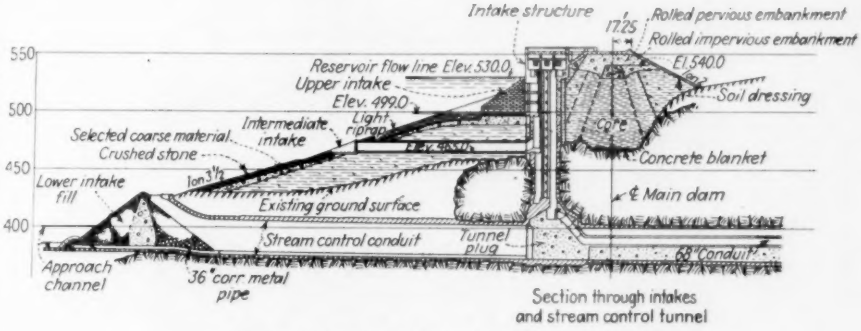


FIG. 4. Outlet Works, Quabbin Dam

inspection and maintenance. Water is admitted to the tower through valves or gates protected by screens and arranged in groups at the several levels. This multiple inlet system has a decided advantage in reliability over the single inlet system of the plug and tunnel type, and is for that reason more suited to the conditions of operation in a reservoir where the lower outlets may not be exposed for inspection and maintenance for periods of many years. In the Quabbin Dam for the supply to Boston, three intakes are provided at different levels (see Fig. 4 of this abstract) into a tower structure constructed in solid rock at a distance from the dam. At the Lackawack Dam for the supply to New York (Fig. 5 of this abstract), there is a similar tower, but the water may be admitted at any part of its height, stop logs being used to confine the flow to the range of depth desired. At both Quabbin and Lackawack Dams the pressure tunnel to which the water passes from the tower carries the water for many miles to the next reservoir in the system.

At the Mathews Dam a single circular outlet tower, constructed at a point remote from the dam, carries six banks of 30-in. hydraulically operated valves through which water is admitted to a wet well (see Fig. 6 of this abstract). From the tower, water passes to a pressure tunnel of 14-ft. diameter, at the downstream end of which are needle valves and a stilling pool, which acts as the intake basin of the pipe-aqueduct.

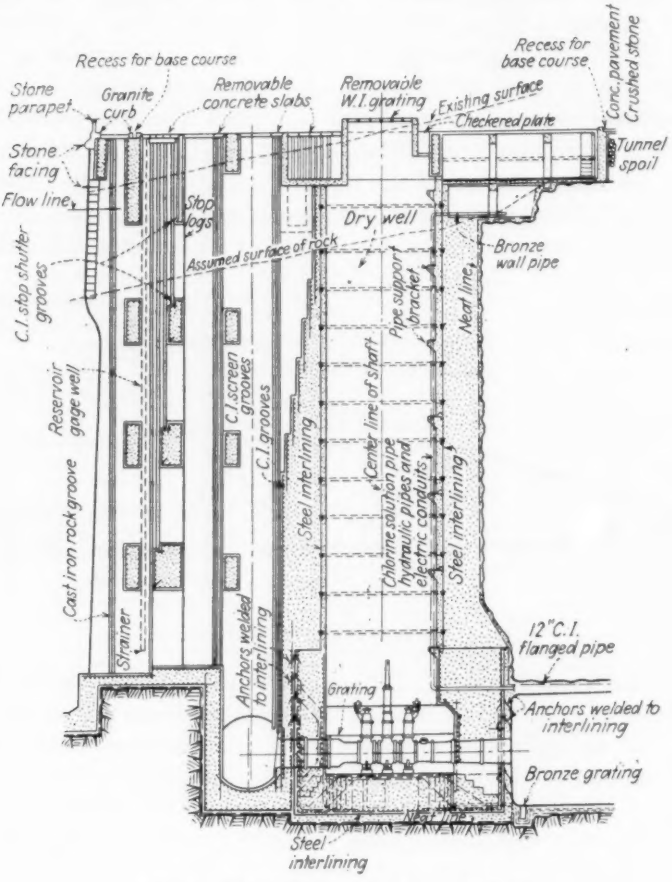


FIG. 5. Outlet Works, Lackawack Dam

II. Supply of Water to Cities

1. Control of Catchment Areas

Broadly speaking, the large cities of the United States are by no means as well placed as Melbourne in the matter of the source of supply. Many of them are forced by geographical and other conditions to take their supplies from lakes, rivers, or wells, subject to some degree of pollution.

Where suitable upland catchments are available, they are in some instances remote; many of them are inhabited to a greater or less degree and not uncommonly part of the land is in private ownership, The more fortunate position which Melbourne enjoys is in part due to the fact that development in Australia was later than in some parts of America, and at a time when the dangers of bacterial contamination were beginning to be understood. Melbourne's more fortunate position is also probably due in part to the process of development, which in America was frequently through private water companies which had not the resources to acquire large tracts of

FIG. 6. Outlet Tower, Mathews Dam; showing movable fine screens

catchments, or the influence to have them withheld from alienation. As a result, in America a great many supplies are regularly chlorinated. Many undergo a most elaborate treatment.

Recreation

Recreational use of catchment areas and reservoirs is permitted under control by some cities and districts in America; others impose rigid restrictions on it; and others prohibit it. The subsequent treatment of the water is of course an important consideration. In the few instances observed in America where water goes into consumption without chlorina-

tion, no recreational or other use of catchments is permitted. If the water is not treated, it can be taken for granted that there is considerable danger of pollution in unrestricted and unsupervised recreational use.

Industrial Use

There are two independent aspects of the question, namely, the danger from pollution which may follow occupation and the danger of destruction of the forest with consequent depletion of the available yield of water.

1. Pollution: The risk of pollution can be reduced by the workers living outside the catchment when it is possible for them to do so; but they still must work for long hours within the area, and even though the most rigorous sanitary precautions are taken, the workers are so scattered and move so frequently from place to place that the requirements cannot be made effective and supervision of them is often impossible.

2. Depletion of Yield. In the past there has been some difference of opinion as to the degree to which the available yield is affected by loss of forest cover in the various forest types. This is at present the subject of intensive research in America.

2. Hydrologic Investigations

Flood Discharges

There has been a considerable advance in the method of attack on the important problem of predicting the greatest flood discharge to be expected from a given area. In the past, empirical formulas, the so-called rational method, and statistical and probability methods have been used. Recent developments have been based on the intensive study of storms and the more accurate determination of runoff characteristics by use of unit hydrographs prepared directly from stream gagings or otherwise.

In the study of storms, the aim is to obtain an accurate knowledge of the actual intensity, extent and duration of major storms. The usual method of recording rainfall—i.e., total precipitation for the 24 hr.—is of limited value. Automatic gagings at a sufficient number of stations to map the variations in intensity with both time and locality are required. Extensive studies of the movement of air masses are undertaken in conjunction with the United States Weather Bureau, and data from observations in any one area are applied by a system of transposition to other areas. From these studies, the variation of rainfall in extreme storms can be predicted, and, by the use of appropriate runoff factors, the variation in runoff.

Yields of Catchments

The factors affecting yield of water from catchment areas include many which are climatic and not controllable, such as rainfall, and evaporation

due to wind and sun. Effective rain and stream gaging will put rainfall studies on a firm foundation. In America, scientifically controlled studies are made of evaporation from large water surfaces.

3. Distribution

Aqueducts

The supplies of many American cities are drawn from catchments comparable in elevation, and in distance from the city, with those of Melbourne, but some cities have been forced to bring water great distances. Probably the longest aqueduct systems are those of Los Angeles which bring water from the Sierras about 350 mi. and from the Colorado River a like distance.

Downstream from storage reservoirs, the stream bed is in some instances used to carry the regulated flow for some distance to the diversion point, as between Hetch Hetchy Reservoir and Early Intake Weir in the San Francisco supply, and Long Valley Dam and the Owens Valley Intake in the Los Angeles Supply. From the latter intake for about 70 mi. the aqueduct is unlined. The remainder of the Owens Valley open aqueduct and the whole of the Colorado River open aqueducts are concrete-lined. Despite these instances, open aqueducts are uncommon in important American supplies. Where they are used in unoccupied forest lands, as at Hetch Hetchy, or across deserts as in the Colorado Aqueduct, they provide a satisfactory and economical arrangement. But this cannot be claimed of a stream bed or open aqueduct in low or sidehill country where there is settlement, if under any possible circumstances the drainage from habitations may enter the channel. This condition has arisen in some supplies, and has led to the abandonment of aqueducts. In the Owens Valley supply, reliance is placed on a very strict sanitary control by the water authority of all potential sources of pollution, on the natural purification to be expected in the travel through the long aqueducts and the many storages of the system, and on eventual multiple chlorination.

In the Eastern States, covered aqueducts have been generally used. These follow much the same gravitational grade lines as would open aqueducts, but are built up above the surface rather than excavated below it. For that reason they are much less subject to the entry of polluted drainage and wind-blown matter; but infiltration does occur in low country. In the Boston supply, some of the old covered aqueducts are to be abandoned, partly because of this hazard. They will be replaced by pressure pipes and pressure tunnels. For the very large diameters, usually required in aqueducts, simple steel pipes are not well suited; but a modification in which a very thin steel shell is covered inside with about 2 in. and outside with about 6 to 10 in. of formed vibrated concrete to make a composite

pipe has found wide use. This type of pipe, 11½ ft. in internal diameter, is being used for the new Boston aqueduct. It is costly to make and handle. Pipe sections are made in 12- and 16-ft. lengths and weigh 40 to 50 tons. Nevertheless, it appears to provide the almost perfect aqueduct, being robust, quite watertight, capable of withstanding high heads, immune to corrosion above or below ground, and to incrustation, and is, as far as can be foretold, of the highest durability. These aqueducts are being laid below the surface as that arrangement provides the least obstruction to cross-traffic in the fairly closely settled areas in which they are placed. This is also of advantage in keeping the temperature of the water low and minimizing joint movement (joints are usually of lead); but in open country they could be equally well laid above the surface with some saving in cost.

The Croton and Catskill aqueducts in the New York supply are covered grade aqueducts, but the new Delaware River supply will be brought in pressure tunnel right from the diversion points (about 100 mi.) under a pressure sufficient to prevent the entry of any infiltering water. In shortness of line, simplicity of arrangements, freedom from pollution, and in general reliability, this system has very obvious advantages. It has comparatively small loss of head through friction, and is free of the great disadvantage in regulation common to all long grade aqueducts, i.e., that alterations in supply must be made at the inlet end, with consequent long delay before the increase or decrease takes effect at the delivery end. From the point of view of immunity from hostile attack in time of war the advantages of the pressure tunnel are unparalleled.

For main distribution feeders within the city limits, large steel and cast-iron mains are common in American practice. These are laid in the streets, and usually in the middle of them. To meet the tremendous demand of New York City—1,000 mgd.—it has been found necessary to drive pressure tunnels of large diameter under the city. These are constructed some hundreds of feet below the surface, and in them sufficient pressure is maintained to provide 50 to 60 psi. in the surface reticulation (connected to the tunnel by risers in shafts in the streets).

City distribution by pressure tunnel has all the advantages described above, and in addition provides freedom from corrosion, and from interference by and to other surface works and utilities. It is clear that as the quantity of water to be delivered to the city increases, and at the same time the use of the streets for surface traffic and for other surface and subsurface utilities, it must become more and more costly and difficult to find room for mains and to maintain them.

Mains

The general principles of distribution of water in American cities are similar to those followed in Australia. Whether water is brought into the city area by gravity or pumped, it is distributed through service basins (reservoirs), and the pressure is usually broken down in steps or zones from the high levels to the low by use of intermediate basins, or less commonly by the use of pressure regulating valves. Distributing mains range downward from about 60 in. in diameter.

As in Melbourne, most American supply authorities are not obliged to maintain any specified degree of pressure. In New York, the statutory requirement is only to deliver water into basements. In the section of lower Manhattan, New York, where values of properties and merchandise are exceptionally high, there are special fire mains laid throughout the district, with special four-connection hydrants. Two large pumping stations are manned continuously in readiness, on a telegraph signal from the Fire Department, to pump, each at the rate of 36,000 gpm., at a pressure of 200 psi., from any one of three different mains, or from the sea, into the fire mains. Provision of special fire mains and pumping plant is not a usual arrangement, the ordinary provision being for the fire authority to pump from the ordinary mains.

Services

Service lines are usually of copper and occasionally of lead or iron. In Melbourne the supply authority owns the main and the consumer owns and maintains the service cock (ferrule cock) and the service therefrom to the fittings in the building. American practice differs substantially. The authority owns the main and the service cock (corporation cock), and usually lays and maintains the service itself to the outlet side of the meter. Meters are usually placed in pits in the sidewalk near the building line, so that practically the whole of the service in the street is maintained by the authority. In most cities, owners make application for the size and type (i.e., domestic or fire) of service required, and, if the size is approved, the authority lays the branch and the meter on payment by the applicant of a fixed charge depending only on the size of service (and not its length). All services are maintained by the authority free of cost to the owners.

There are some very definite advantages in this arrangement:

1. Where there is only one main in the street, and it is laid near one side, owners on the remote side are not penalized in having extra cost for laying and maintaining their services. All services of the same diameter are laid by the authority and charged at an averaged flat rate, and main-

tained without charge. Laying charges cover the cost of laying and renewing at an estimated life. Maintenance charges are met out of rates.

2. There is less need for duplicate mains. The supply authorities can afford to maintain power equipment for boring under pavements for laying of services.

3. Service connections can often be made to the mains when they are being laid, at considerable saving in cost.

4. The problem of insulating couplings does not arise in America. Electrolysis of service pipes is not general throughout the Melbourne water-supply area, nor is it of uniform intensity where it does occur. The percentage of serious cases is small. It is not desirable for the authority to discriminate by ordering some owners to provide couplings and others not. If, however, the authority maintains the service, protection may be given to meet the needs of each particular service, and varied from time to time as required. The cost of protection of services against electrolysis is thus kept at a minimum and borne by the rate-payers as a whole, as it should be.

5. The necessity to obtain the owner's consent before work can be done on a service pipe in the street is removed. In Melbourne this has been a severe restriction on the Board's survey of the incidence of corrosion.

6. A cheaper and more efficient service is given to the public. In most American cities, the emergency gangs who stand by to make repairs to mains are available, or similar gangs are, to deal also with services. Thus services can be repaired if necessary at night, or over week-ends, or on holidays.

Corrosion

Of recent years there has been much activity in both the preventive and the corrective aspects of electrolysis. Steps have been taken to reduce the leakage of traction current to the soil, to prevent it from passing from the soil to metallic underground structures, and where necessary to collect it harmlessly from them by metallic connections. These methods include control of the spacing of sub-stations, and track-voltage drops; and, the provision of protective coatings, and of electrical devices such as drains and cathodic protection.

Even in cities where electrolytic corrosion has in the past been a serious problem, these measures have proved generally effective in greatly reducing damage. Another factor which has had a very great influence in reducing the incidence of electrolysis is the wide-spread replacement of tramway (street car) systems with gasoline-driven buses or trolley buses on rubber tires. While electrolysis is still a problem in many localities, attention is being directed to the general aspects of corrosion, and more particularly to soil corrosion and the part played therein by certain bacteria. Special

equipment and methods have been devised for measuring the relative corrosiveness of soil, and surveys are made by many water authorities to measure and record it along the routes of their important mains.

Protective Coatings

Protective coatings are in a general way similar to those in use in Australia, although the importance of coatings is less in many cities owing to the use of a far greater proportion of cast-iron pipes, particularly in the larger diameters.

1. Bituminous Coatings: Bituminous coating practice is far from uniform throughout the country. Some authorities still use natural asphalts or mineral bitumens and in some places coatings are still being applied by dipping. For protective coatings, the American Water Works Association has published a standard specification which may be taken as representing the best standard American practice. In a few important respects it differs from the most recent practice of the Melbourne Board. Grit-blasting is used for cleaning pipes; heat is not applied except for drying, and then only to very moderate temperatures; and priming is done on a cold or near-cold pipe. Enamels are applied while hot. The inside and outside coatings are applied by pouring the enamel on the rotating pipe at a controlled rate through a distributing head which is traveled along the pipe. Finally a shielding wrap of felt is applied o . the outside over the hot enamel.

The primers and enamels in use in America in water works are all proprietary articles, and full information concerning their composition and method of manufacture is not available. Modern practice requires them to be of coal-tar base, and the standard specification referred to above sets out certain fairly rigorous physical tests. Those products commonly in use under this specification are described as "Processed" or "Plasticized" pitch. The enamels differ from those used by the Melbourne Board in that this processing induces certain physical and chemical changes in the pitch itself, making it less liable to run at high temperatures and shatter at low ones; whereas in the Board's enamels this is effected by mechanical admixture with inert filling materials such as asbestos and limestone. The American enamels are superior to the Board's in their performance under the usual tests; they have an equally low water absorption; and are tough and strong, and handle as well, if not better, in the field. They are not at present available in Australia; but if they were it would be desirable to have a fuller knowledge than can yet be obtained of their chemical composition and physical structure, and possibly to apply some accelerated tests to examine the permanence under all conditions of use of the change brought about in processing.

Sandbedding of coated mains is common practice, and in certain types of clay, or in rock, pipes are sometimes shielded all round with sand refill.

Cement Coatings: Cement coating practice in America differs somewhat from that in Melbourne. In many cities cement lining is not applied to cast-iron reticulation (gridiron) pipes before laying, and cement lining *in situ* is not yet practiced extensively. This difference in practice is largely explained and justified by the different corrosiveness of the water carried. Melbourne water has a low mineral content and is neutral or very faintly acid. But waters which are of high mineral content, hard and faintly alkaline are much less corrosive, and tend rather to deposit lime on the walls of the pipe. With such waters, cement linings are not warranted. In some supplies lime dosage of the water produces the same result. Cement lining of large steel mains has been done manually to a limited extent in the past. Recently a mechanical process which can be used before laying or *in situ* has been developed. The lining produced appears strong and effective. It is stated that in America there are about 3 million lin.ft. of main of 36-in. diameter and over, in service upwards of 20 years, to which this treatment could be applied.

Concrete or mortar applied by the cement-gun is sometimes used as an outside coating for pipes which will be laid in particularly corrosive ground, or where it is considered that special protection of the bituminous coating from mechanical damage is desirable.

3. Paint Coatings: Paint coatings are applied to steel work above ground. Common practice calls for two coats of red lead and one or two of aluminum paint, each coat being given a coverage of 500 sq.ft. per gal. It is held by some authorities that there is a detrimental action between red oxide of lead and metallic aluminum, and that with aluminum a zinc chromate paint should be used.

It is common practice to require that the vehicle shall be a synthetic resin varnish using an alkyd or phenol-formaldehyde resin.

In preparation for painting, the best practice calls for complete removal of scale by sand-blasting or picking with phosphoric acid.

Metering

There are many variations in the extent of metering, and in the basis of charging for water. Some cities make charges on a two-part basis—one a flat rate, minimum charge, or some other type of rate, which is payment for readiness to serve; the other, a charge for water used as measured through a meter. In other cities, the basis of charge is substantially rating only. The rating charge is not usually based on valuation of property, as in Melbourne. For instance, in New York it is known as a "Frontage Rate":

"Frontage rates vary from $6 for a one-story building 16-ft. wide to $21 for a one-story building 50-ft. wide. To these rates, $3 is added for each 10 ft. in excess of 50 ft. frontage and $1.50 for each story above the first. The primary frontage rate is predicated upon the building being occupied by one family, containing one bath, and one water closet. For each additional bath, $4.50 per annum is added; for each additional water closet $3 per annum, and for each additional apartment or family $1.50 per annum."

At Denver, practically the whole of the water consumed is sold on a single rating tariff—the basis being a schedule of charges for different fittings.

A common two-part tariff is that of a fixed minimum charge depending on the size of service, plus a charge by measure.

It has sometimes been questioned whether the general metering of services is justified, on the ground that in many of the services the minimum consumption, or the allowance, is only exceeded slightly or not at all, and as the meters earn little revenue the expense of metering is wasted. If there is an unlimited supply of water available, or, in more general terms, if the limit to the extension of the supply is only economic, e.g., in the cost of pumping and purifying, as at Chicago where water is pumped from Lake Michigan, this contention may have some weight. But where there is a limit—even a distant one—to the water available, as is the case in most supplies derived from upland catchments, every reasonable precaution should be taken to eliminate waste.

Organization

In some of the larger cities, the supervision and inspection of supplies, the detection of pollution hazards and waste, the making of emergency repairs, and maintenance of the system—that is to say, the organization—parallels that of the Melbourne Board's Maintenance Branch. In New York, where eight million people are supplied in an area of less than 350 sq.mi., the area is divided into five independent districts coinciding with the separate Boroughs—Bronx, Brooklyn, Manhattan, Richmond, Queens. In each is a District Office with an Engineer in Charge. Districts are subdivided into 4, 3, 1, 3, and 4 subdistricts respectively, each under a Foreman, to whom the operating staff answers.

In San Francisco, the supply-area of less than 100 sq.mi. contains 750,000 persons, and is operated from one central depot.

In Los Angeles, there are 1,500,000 persons and the area of 450 sq.mi. is divided into five districts, each under a Superintendent with an engineering, clerical, and outside staff.

The necessity for decentralization is greater with greater area and with greater population.

III. Future Policy

Fundamental research in America is to a large extent carried out at specialized centers, such as the several national research laboratories and the research organizations directed and maintained by groups of industries, and in educational institutions (which are in many instances richly endowed for the purpose). The application, however, of fundamental knowledge to particular problems is undertaken in the laboratories of the authorities concerned, and the many special problems which arise out of the development of new methods and the changing industrial and technical life of the community are there subjected to constant study by staffs of trained workers.

It is the universal practice of the authorities responsible for major projects, and of those concerned with the supply of water to large cities, to maintain such laboratories. In the latter are also conducted the testing of materials; the routine chemical, bacteriological and microscopic examination of the water supplied; and the investigations and model studies associated with engineering design.

Traveling Laboratory Control of Bottlers' Operation

By Bert Wells

PERHAPS the best introduction to a description of the traveling laboratories used by The Coca-Cola Company in its control of bottlers' operation is a brief outline of the problems which prompted their use. Any discussion of the control of bottlers' operation should logically begin with the consideration of the water used in the beverage. In discussing standards of water quality the A.W.W.A. *Manual of Water Quality and Treatment** states:

"Present opinion concerning the characteristics of good quality in drinking water may be epitomized as follows:

"*A water supply should be clear of neutral taste, of reasonable temperature, neither corrosive nor scale-forming, not so mineralized as to produce unfavorable physiological effects, and containing no organisms capable of producing intestinal infections.*"

Water Quality Requirements

The specific requirements for water to be used in bottling "Coca-Cola" should be listed under the headings—Mineral, Physical and Sanitary.

Mineral

The total alkalinity should be less than 7.5 gpg. (128.25 ppm.). Obviously any alkalinity present in the water will react to neutralize the acid present in the syrup and any major reduction in this acid will reduce the required tartness of the taste. The total solids present should generally be less than 50 gpg. (855 ppm.). This is a general figure and represents an average condition beyond which a brackish or saline taste may appear in the water itself. Such taste is objectionable because of its effect upon the flavor of the beverage. Obviously dissolved mineral matter which is not alkaline in character might have a greater influence on taste than other

A paper presented on June 22, 1942, at the Chicago Conference by Bert Wells, Chemist, Chemical Control Dept., The Coca-Cola Co., Atlanta, Ga.

* *Manual of Water Quality and Treatment.* Prepared and published by the Am. Water Works Assn. (1940). p. 13.

types. Dissolved iron should be less than 1.5 ppm. Amounts in excess of this may produce a metallic taste in the drink and may cause a brown or brownish ring to form on the glass in the neck of the bottle. Water should be free from hydrogen sulfide because of its influence on the taste. Likewise chlorine and chlorophenol should be absent.

Physical

The turbidity of water should be less than 1.0 ppm. If finely divided solid matter is allowed to go through the bottling processes, it will provide nucleuses on which the carbon dioxide will collect and cause foaming just prior to the time the bottles of finished beverage are capped. This results in a loss of the carbon dioxide and subsequent poor carbonation of the beverage. The small particles may also tend to coalesce with some of the elements that go to make up the flavoring and result in a sediment in the finished beverage. Color of water used for bottling should not be higher than about 10. It is not particularly harmful in itself, but usually indicates that the water has a high content of organic matter. Tastes and odors in beverages are more objectionable than in drinking water because of possible reactions with the flavors in the syrup. It is difficult to state the top limit of organic matter, because, with the difficulty in determining just what types of organic matter are present, it is not always possible to predict what will happen in the finished product. Colloidal organic matter may often cause a separation of the flavoring oils in the syrup and bring them to the top of the bottle in the form of a ring. Dissolved organic matter may cause off-tastes.

Sanitary

Water should conform with the sanitary requirements of the U.S. Public Health Service. To assure themselves of an adequate supply of satisfactory water at all times a great many bottlers of "Coca-Cola" have installed various types of water treating equipment. Many of these are used simply as insurance against possible seasonal variations or emergency conditions. A number of plants are using only sand filters and activated carbon purifiers to take care of the odors and tastes that may occur. In other cases coagulating or alkalinity reduction equipment has been added to the installation. The use of either of these latter types of equipment together with chlorine provides a complete water treatment.

Design of Traveling Laboratories

It is for the control of water quality to satisfy these various requirements that the traveling laboratories were introduced and toward this end the personnel of the laboratories devotes a great deal of its time at the various bottling plants.

The traveling laboratories were designed and constructed to meet the requirements of testing for and assisting in quality control in a bottling plant. By making minor construction changes in a stock model of a sixteen-foot trailer, ample space was provided for the laboratory (Fig. 1). The lighting system and electrical apparatus was designed to operate on 110 volts a-c.; the total load was kept at a minimum so the trailer may be plugged in at any convenient outlet. The lighting system consists of overhead fluorescent lights and small emergency lights which may be operated from the battery of the automobile which is used to pull the trailer.

The basic apparatus in the trailer consists of a specially designed water testing cabinet, microscope, centrifuge, bacteriological incubator, constant speed stirrer for coagulation test, pH comparator, hot water bath, autoclave for the production of bacteriological media, and dead-weight gage tester. In addition, miscellaneous glassware and such specialized equipment as required are included. Work tables, a small sink, with water storage and waste tanks, cabinet space for stationery, forms and books, as well as a small filing cabinet complete the furnishings.

The water testing cabinet is designed for the volumetric determination of alkalinity, hardness, sulfates, chlorides, chlorine and iron (qualitative). The microscope and centrifuge are used to separate and examine sediments in water and to determine the presence or absence of algae. Bacteriological tests include total count and gas formation on the water in various stages of its treatment at a given plant, as well as a complete bacteriological survey of the bottling operation. The dead-weight gage tester is used to check the accuracy of the pressure gages in a bottling plant. This is essential in controlling uniformity of the amount of carbon dioxide gas in the finished product. Other equipment is provided to assist the personnel in making such additional tests as are necessary for quality control.

Duties of Laboratory Personnel

The personnel of each traveling laboratory consists of two men, one of whom is either a graduate chemist or chemical engineer, and the other, a plant technician. The chemist's duties include the running of all tests and determinations. The plant technician assists the chemist, particularly in his work on the water treating equipment. Both men are trained in the adjustment and servicing of such equipment. The plant technician makes a complete plant and equipment survey, including physical equipment and its operation, from the standpoint of control of the bottling process. Both men collaborate on a survey of the sanitary conditions of the plant. Bottling plants vary a great deal in size and in the amount of equipment used. The average time required for a survey of a plant is

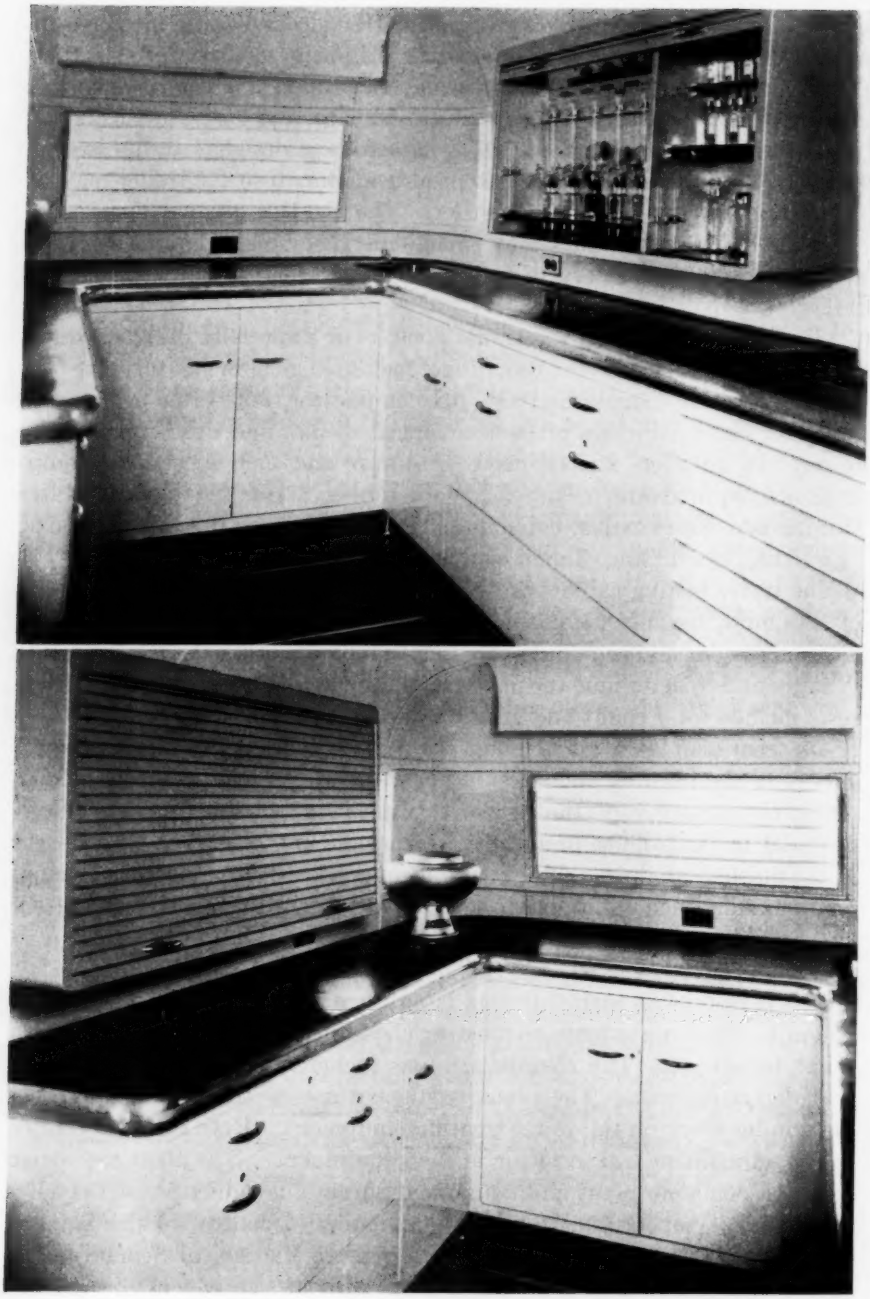


FIG. 1. Two Views of Interior of Traveling Laboratory; showing arrangement of equipment

about one day. Naturally, if conditions warrant it, the laboratory unit remains at a plant as long as is necessary.

One of the duties of the chemist, aside from his work in the individual bottling plant, is to become familiar with the local water supply. It is felt that the local problems often play such an important part in water supply that it would be most advantageous for the chemist to be familiar with the local municipal plant and its personnel, as well as for the municipal plant personnel to be familiar with the local bottler's water problems and requirements. To further this effort the chemist is asked to fill out a water works questionnaire, including: source of supply, seasonal variation in total solids and alkalinity, details of treatment used, whether or not any changes in supply or treatment are in progress or contemplated, and a copy of the analysis of the water as it is delivered to the bottling plant. One copy of this questionnaire is sent to the company's Chemical Control Department, another copy to the office which administers the traveling laboratories and a third, is kept in the laboratory. The data accumulated from these questionnaires have proved very valuable in the work of the Chemical Control Department.

Company Recommendations to Bottlers

The company's recommendations regarding the types of water treating equipment purchased by bottlers are largely based on the fact that the seasonal variations in water, as well as emergency conditions, must be taken into account. Over a period of years of experience it has been found that every bottling plant should be equipped with sand filters and activated carbon purifiers. This basic equipment provides insurance against unexpected and occasional occurrences of chlorophenol or chlorinous tastes.

During the past few years it has been recommended that each bottling plant be equipped with coagulating or alkalinity reduction equipment and that chlorine should be used in connection with either. Because of the basic differences in requirements of water quality for the municipal supply and the bottling plant, it has often been found advantageous for bottling plant operation to coagulate the water from the municipal supply even though it has previously been coagulated. This does not imply that the water from the municipal plant is not perfectly satisfactory for drinking water and general use. Coagulation in a bottling plant is simply added insurance against unusual conditions which may result in slight increases in turbidity or the presence of finely divided solid matter.

It is further recommended that, if the raw water exceeds 5 gpg. (85.5 ppm.) of alkalinity, alkalinity reduction should be used with coagulation. It will be recalled that the requirements regarding alkalinity call for reduction in any water containing more than 7.5 gpg. (128.25 ppm.).

This is not necessarily a conflict, but rather a tightening up in requirements. In order to avoid confusion it might be mentioned that the hardness of water which goes into the finished product is not of concern unless it exceeds the 50-gpg. (855-ppm.) limit of dissolved mineral matter. The company is interested in reducing the alkaline components of the total hardness. Because of the comparatively small amount of water treated in a bottling plant, it is economically feasible to use more expensive treatment or larger doses of chemicals than would ordinarily be used by a municipal supply. This applies particularly to the use of chlorine.

Use of Chlorine Treatment

Past experience indicates that chlorine is probably the most useful chemical for bottling plant water treatment. In some cases where the municipal supply contained up to 0.5 ppm. residual chlorine at the bottling plant difficulties have resulted. On the other hand, experiments conducted in the Chemical Control Laboratory, as well as plant operations in the field, have confirmed the fact that it is sometimes necessary to use sufficient chlorine to produce a residual of as much as 8 ppm. after 3-hr. retention.

This observation was strikingly confirmed last summer, in a plant using water from a municipal supply. The municipal plant drew water from a reservoir, coagulated it and treated it with chlorine to carry a residual of 0.3 to 0.6 ppm. as it entered the mains. A protracted drought had lowered the water in the reservoir seriously and a considerable amount of colloidal and soluble organic matter was present in the water received at the bottling plant, though the turbidity of the water was less than 1.0 ppm. Some days after being bottled, the bottled product developed a sediment which shortened its shelf life slightly. Alum coagulation with the addition of 2 ppm. of chlorine with $3\frac{1}{2}$-hr. retention did not materially reduce the trouble.

Samples of the water, as well as the finished product, were sent to the Chemical Control Laboratory for examination. Cataphoretic examination of the water received by the bottling plant revealed considerable amounts of colloidal material. Laboratory coagulation using as much as 4 to 5 gpg. (68.4 to 85.5 ppm.) alum did not totally remove the colloidal matter. Experiments showed that the input of 10 ppm. of chlorine and 3-hr. retention were required to satisfy the chlorine demand of approximately 2 ppm. Further examination revealed that alum coagulation, plus 10 ppm. chlorine with 3-hr. retention removed the colloidal matter. Water subjected to the above treatment was de-chlorinated and used in making several bottles of finished product. All of these bottles were perfectly satisfactory in all respects.

The bottler was advised of the laboratory findings and increased the chlorine in the treating plant to produce a residual of 8.0 ppm. at the sand filter effluent. No further difficulty has been experienced since that time. Though this occurrence represents only one plant, it is presented to illustrate the necessity for large chlorine dosages in many plants.

Through the medium of reports, the Chemical Control Department has kept constantly informed of all work done by the laboratory in the field as well as of all new developments and difficulties. One of the difficulties often experienced in the field is the production of a good floc in some plants which are using previously coagulated water containing small amounts of alkalinity and turbidity. Considerable work has been done on this problem and it is hoped that valuable information will be secured.

Substitute and Alternate Materials for Service Pipe

By E. E. Smith

THE words, "substitute" and "alternate," used in reference to service pipe materials are nearly synonomous, their difference being merely an indication of the temporary or permanent nature of the material. For many years service pipes from $\frac{3}{4}$ to 2 in. in inside diameter have been fabricated almost exclusively of copper, and those 4 in. and larger in size, of cast iron. In this discussion, then, type K copper tubing will be considered the basic material for small services, and any variation therefrom, a substitute or alternate material. Before proceeding with this discussion, however, it should be pointed out that none of the information presented is essentially new; rather it is presented as a review of possibilities.

By November 1, 1941, copper service pipe was practically removed from the market, so that it became evident that substitutes or alternates would become necessary as inventories of copper tubing were depleted. At Lima, every effort has been made to conserve copper tubing for the particular locations where it alone can be used, employing other materials in locations where their peculiarities can best be put to advantage.

The substitute or alternate materials in service sizes of from $\frac{3}{4}$ to 2 in. in inside diameter are as follows:

XS or XXS lead
Cast iron, in screwed joints, 5-, 10- and 15-ft. lengths, $1\frac{1}{4}$ in. in diameter
Cast iron, in screwed joints, 6-, 12- and 18-ft. lengths, $1\frac{1}{2}$ in. in diameter
Cast iron, in screwed joints 9- and 12-ft. lengths, 2 in. in diameter
"Tube-Loy," type K, $\frac{3}{4}$ and 1 in. in diameter
"Tube-Loy," type A, $1\frac{1}{2}$ and 2 in. in diameter
Wrought irons
Plastic tubing

A paper presented on May 14, 1942, at the Ohio Section Meeting, Toledo, Ohio, by E. E. Smith, Gen. Supt., Dept. of Water & Sewage Treatment, Lima, Ohio.

Each substitute or alternate material has its own peculiar advantages and disadvantages, briefly as follows:

1. Lead requires wiped joints, calling for skilled labor, but is permanent, convenient, ductile and reliable.

2. Cast iron is permanent, though relatively brittle. For changes in direction it requires fittings which are usually malleable.

3. "Tube-Loy" is new and relatively unproved. It is, however, convenient, and can be wiped, flared or sweated in fittings, and is probably permanent.

4. Wrought iron is strong and tough, but rexuires fittings for more than slight changes in direction. Its permanency depends on the character of water and the durability of fittings.

5. Plastic tubing has not yet been adapted to use with hot water, nor is it freely available (see editorial note below).

TABLE 1

Price per Foot for Various Sizes of Service Pipes of Substitute or Alternate Materials

MATERIAL	SERVICE SIZE—INTERNAL DIAMETER				
	¾ in.	1 in.	1¼ in.	1½ in.	2 in.
XS lead	$.31	$.42	$.53	$.71	$1.22
XXS lead	.42	.53	.69	.99	1.72
Cast iron	—	—	.20	.22	.27
"Tube-Loy" type K	.19	.23	.39	.37	.54
"Tube-Loy" type A	—	—	—	.73	1.20
Wrought iron	.14	.19	.25	.29	.40

Cost comparison of these substitute and alternate materials is, of course, important. Table 1 gives the price per foot of various materials according to the most recent quotations, subject to quantity discounts and market changes. It will be noted from this comparison that wrought iron services in the smaller domestic sizes are cheapest, "Tube-Loy" next, and lead most expensive. In the larger service sizes, cast iron is cheapest, followed in order by wrought iron, "Tube-Loy" and lead. In view of the limited availability of wrought iron, the desirability of using "Tube-Loy" for the small services and cast iron for the larger is indicated.

EDITORIAL NOTE: Since Mr. Smith prepared and presented this interesting paper on service line materials, the availability of certain materials has changed. Copper remains on the excluded list as far as purchase is concerned. Unofficial advice from the Power Branch of the War Produc-

tion Board indicates that a water department which has a stock of copper tubing available may use it in installing service lines insofar as its judgment indicates the necessity for copper. The water utility cannot sell its stock of copper tubing to private contractors.

Due to the current limitation on general construction, lead service line material is more available than it was in May. It can be obtained on the ratings presently conferred by Preference Rating Order P-46. At the present time "Tube-Loy" can be obtained upon the same rating and used in water services where the water is not corrosive to lead or lead-alloys.

Mr. Smith's reference to plastic tubing is correct insofar as it is adaptable for hot water service. The Dow Chemical Company's "Saran" is now available in $\frac{3}{4}$-in. (outside diameter) size. It is manufactured in four wall thicknesses. A communication from the manufacturer contains the following information:

"This tubing can be manufactured in four wall thicknesses, which are as follows: 0.045, 0.062, 0.093 and 0.125 in. The 0.062-in. wall is considered a stock size tubing, while the other three are made to order. A minimum order on the 0.045-in. wall runs 10,000 ft., and on the 0.093- and 0.125-in. walls, minimum orders of 5,000 ft. are required. The tolerances on the $\frac{3}{4}$ in. od. tubing are 0.700 to 0.755 in."

The tubing of the 0.062-in. wall thickness in the $\frac{3}{4}$-in. size weighs 1.5 oz. per lin.ft. The general price range on this material is from 38.4 down to 19.2 cents per foot, depending on the quantity ordered. The limit bursting pressure of this tubing exceeds 1,000 psi.

The above information is recorded not as a recommendation of the material but as a matter of information for any water works man who may wish to investigate the qualities of the material. When it is installed, moderate heat is applied to soften the tubing and the end of the tubing flared for use with the earlier type flare fitting used with copper tubing.—*Harry E. Jordan.*

The Filter Backwash—Sand Expansion and Velocity

By Roberts Hulbert

LOOKING back not so many years, it seems that one would have scarcely thought of discussing ways and means of keeping rapid sand filters clean. It would have been difficult then to have found anyone willing to argue that a clean filter made a better water filter. Fashions change rapidly, so that now we find dirty sand and muddy filters quite out of style. Accepting the principle of clean filter sand, recent controversy necessarily has narrowed down to a question of methods of filter maintenance.

Considering the very different conditions of design, equipment and hydraulics that prevail as between different filters, is not the question of how to obtain the most efficient backwash in each particular plant pretty much a local problem? Believing that to be so, the author excuses himself from venturing to recommend any universal remedy. There are, however, some fundamental concepts involved in backwashing filter sand which are often overlooked, but which, as a matter of fact, do give it the aspects of a scientific process. As such, it appears to be a procedure worthy of thoughtful study, in anticipation that a better understanding of the principles involved must eventually lead to better control of the process, and this in turn, to an improvement in results therefrom. The keynote to this brief discussion is perhaps this: *Know what happens to the filter layer during backwash, and why it happens.*

Looking into the matter of how to gage the intensity of the filter backwash, one should first try to settle the question in his own mind as to which of two indicators is best for this purpose; *velocity* (rate of wash water rise), or *expansion* (the resulting sand rise).

By way of comparison, which indicator is suitable for determining the total alkalinity of water—methyl orange or phenolphthalein? You know that methyl orange is used because it indicates the "total alkalinity," that phenolphthalein is good for only certain kinds of alkalinity. Similarly a

A revision of a paper presented as a part of a symposium on November 7, 1940, at the Four States Section Meeting, Wilmington, Del., by Roberts Hulbert, Asst. Supt. Filtration, Detroit.

measurement of the sand expansion resulting from a filter backwash indicates the total, combined effect of all the factors involved, not merely one of them. And backwash velocity *is* only *one* of the several factors which determine the resultant percentage of sand expansion, and hence tells only its part of the story of what is happening during a filter wash. Other important variables, vitally concerned, are such factors as washwater temperature (viscosity), size, shape, grading, and specific gravity of the sand or other material used as a filtering medium. If values for all these factors are known, it is possible to substitute in an equation and solve for expansion mathematically. Practically, however, it is a simple matter to measure the sand rise in any filter during backwash, and calculate this in terms of percentage expansion by depth. One then has a true index of the work being done on the sand layer by the rising wash water, regardless of whether results are good, bad or indifferent.

Backwash Velocity

If it is possible to apply velocity enough to a filter to obtain satisfactory cleansing, it then becomes desirable to keep this efficient kind of wash invariable, something which cannot be done by holding the wash rate constant, but, on the contrary, can be accomplished only by changing the velocity of wash water, from time to time, to maintain the indicated sand expansion a constant, which otherwise would vary inversely with water temperature. Similarly, even at the same water temperature, the sand expansion produced by any given wash rate differs as between different filters, and filters in different plants, because of the influence of the varying character of filter sand. It may be worth while to consider the particular effect of variables such as size, shape, specific gravity etc., briefly in turn.

First, assume that two filters differ only in respect to the size of sand comprising the filter layer, one containing 0.45 mm. sand (size than which 30 per cent is finer) and the other 0.55 mm. size. All other factors being the same, it is to be noted that (at 70°F. water temperature) the finer sand will require a backwash velocity of 24 in. per min., as compared to 34 in. per min. for the coarser, for an equivalent 50 per cent expansion. In this instance a 22 per cent difference in sand size calls for a 41 per cent difference in wash rate to obtain the same sand rise; in other words, a 24 in. per min. backwash expands the finer sand 50 per cent, the coarser only 33 per cent. Evidently these two sands do not behave at all alike at the same velocity wash. Why this marked difference in expansion effect? It is purely a matter of frictional effect between water and sand surfaces, the coarser sand having less surface per unit volume for the upflowing water to push against —hence, not so much lift. This frictional effect increases with velocity, the greater the velocity the greater the sand lift, and also, doubtlessly, the greater the sand surface scouring or cleansing effect.

Another factor which affects expansion at a given velocity is sand grain shape. Angular sand of identical grain size and specific gravity will show higher expansion, because its surface is greater per unit volume, compared to round grain sand. Here again velocity governs friction, and friction between water and sand governs expansion. If more friction between water and sand insures better cleansing of the latter (and it seems it must), the higher the wash velocity the better.

Clean, dry, silica sand has a constant specific gravity of 2.65. If the wash fails to clean all the sand surfaces perfectly, then the gravity of the sand is reduced gradually by an accumulating, moist, gelatinous coating, particularly affecting the sand in the upper layers of the filter. During backwash these lighter particles then tend to float at a higher and higher plane in the filter, until eventually, when their terminal velocity has become less than the velocity of wash, they are washed out of the filter. The only remedy for such a condition is to clean the sand and thereafter apply a higher wash rate, not reduce the latter in order to hold light, dirty sand in the filter, a common mistake which only aggravates the trouble. The velocity of wash required to produce, say 50 per cent expansion, means the velocity necessary to raise a *clean* sand layer one and one-half times its settled depth. The optimum sand expansion, or that which indicates the most efficient wash, means an optimum determined on clean, uncoated sand of normal specific gravity.

Wash two layers of the same sand, one deeper than the other, at the same velocity (measured always above the expanded sand): the deeper layer shows a greater sand rise than the shallower, but greater in exact proportion to depth, so that when calculated as percentage of the settled depth of the layer, the expansion turns out to be the same for both. For the sake of keeping the index comparative, and independent of the depth of the filter layer, expansion should always be expressed in terms of percentage by depth.

Finally, consider the influence of changes in wash water viscosity from season to season, which varies inversely with water temperature. Experiments at Detroit (1) indicate that a sand of 0.50 mm. average size will require a 16 in. per min. wash rate for 50 per cent expansion at 32°F., as against 24 in. per min. at 70°F. Riddick (2) gives an even more striking comparison for approximately the same sized, but differently graded, sand. He states that 18 in. per min. velocity at 32°F. is required, compared to 35.5 in. per min. at 77°F., for 50 per cent expansion. Allen (3) states that, in general, sand expansion is doubled by a change in water temperature from 100°F. to 50°F. The specific viscosity of water doubles as a result of a change in temperature from 70°F. to 32°F., and it happens that the sand expansion produced by water near the freezing point is nearly double that of water at summer temperatures.

Again, the explanation of this is friction. Decreasing water temperature results in increased friction between water and sand, because the colder the water the more viscous, less fluid, it becomes, and the greater the resulting friction between it and the suspended sand particle surfaces. How does an increase in viscosity affect the removal of dirt adhering to the sand surfaces? If you use the same wash rate on your filters the year around, perchance you may have noted, that the filters wash cleaner, and that the sand remains in better condition during the winter months. If so, is it not logical, if possible, to increase the summer wash rate enough to give the same sand expansion effect that is procured in winter, and by so doing bring about the considerable improvement that the winter wash shows over summer. When the operator finds out what expansion is necessary to maintain an efficient backwash, it is well to remember that the way to keep this efficient wash constant is to vary the wash rate to produce the desired constant sand expansion. The average velocity required may be anything—high, low, intermediate, or what have you.

The writer wishes to make it plain that he is not an advocate of a mythical, high-velocity wash. High and low are relative terms, meaningless without some point of reference. A death rate of 50 per 100,000 may be low for cancer, but very high for typhoid fever. Thus the velocity required to maintain that constant sand expansion percentage, which experiment has shown to indicate the best possible job of filter cleaning, may turn out to be high or low, as you choose to call it. One can be certain, however, that it will be much higher in summer than in winter, and not at all likely to be the same as the most efficient wash rate for filters in some other plant.

Sand Expansion

Can one recommend a certain percentage expansion as indicating a good wash for all filters, everywhere? It is the author's belief that filters in different plants do not clean equally well at the same expansion backwash, any more than any one filter washes equally well on the same velocity wash the year around. Surely different filters exhibit marked differences in sand size composition. Although the percentage void (space between grains) is the same for all sizes of similiarly shaped sand at the same percentage expansion, the intersticial velocity of water up through the coarser sizes when expanded a given percentage is much greater. If we assume the flow of wash water through expanded sand is capillary, the frictional drag between water and sand surfaces then increases in proportion to velocity (as the square of the velocity in the case of turbulent flow). This means that, in reference to two sands of 0.45 mm. and 0.55 mm. sizes, the velocity through the larger size would be at least 41 per cent higher at the same 50 per cent sand expansion. Such an increase in velocity through coarse sand is important,

because adhering dirt is washed off only when the friction between water and dirt surfaces becomes greater than the adhesive forces between dirt and sand, and this frictional effect is a function of velocity. The coarser the filter sand the greater the velocity which can be applied, and it follows, the greater cleaning effect exerted by the wash.

There are other arguments favoring the use of coarse filter sand. The greater the size the less the actual sand surface there is to be cleaned per given volume. A cubic yard of 0.55 mm. size has about one-third of an acre less surface than does a yard of the 0.45 mm. size. It should be noted also that, at the same expansion, coarser sand particles are separated by very much larger pores, the area of which varies in proportion to sand grain diameter. Through these larger pores dirt can escape more freely, and through them, the velocity of water being higher, it will escape more rapidly. Again, in the case of coarse sands, more abrasive effect is realized by collision of the grains during suspension, because of the greater energy involved.

Plain observation, and the results of experiment, also lead to the conclusion that coarse sand filters wash cleaner. Stanley (4), in summing up the results of co-operative filter sand experiments conducted a few years ago by the A.S.C.E. Committee on Filtering Materials, has this to say in regard to sand size—"top sizes varying from 0.6 to 1.0 mm. seemed to give very satisfactory results, while sizes of 0.5 mm. or less gave short runs and were difficult to keep clean."

Fine sand filters are more apt to be afflicted with mud balls than are coarser ones. The use of a backwash of sufficient intensity to keep the sand itself perfectly clean may not entirely succeed in preventing mud balls from forming in the "schmutzdecke," or rolling mud scum which floats on the sand surface during the wash. Like a particle of dirt, the embryo mud ball will wash off if the rising velocity of water above the sand is greater than its terminal velocity. Considering the "schmutzdecke" as nothing more than an agglomeration of mud balls in various stages of growth, it is apparent that somehow, perhaps during the filter run, these must have become dense, or increased in size, or both, to such an extent that their terminal velocity exceeds the velocity of water rise above the sand, but is still less than that through the upper expanded sand layers. Seeking a velocity level for equilibrium, the embryo mud ball rolls on the sand surface during the wash, a process which increases its size, and its terminal velocity. When the latter exceeds that through the upper layers of sand, the necessity for equilibrium causes the ball of mud to seek a new, higher velocity level, which is within the sand, and it sinks to that level. It sinks into a fine sand layer before it reaches the size at which it will sink into a course one, which explains the not uncommon occurrence of small mud balls throughout

filters made up of a fine sand, in some of which, both by observation and test, it is apparent that the filter sand itself has remained perfectly clean. Growth of these small mud balls may continue after penetrating the layer, but the first small ones in a fine sand layer are liable to escape early detection.

These all appear to be valid arguments favoring the use of the coarsest filter sand possible, first consideration being given, of course, to the character of water to be filtered and its pretreatment. It should be washed at whatever constant sand expansion that experiment has shown to indicate the most efficient backwash, and if this is sufficiently high to keep the sand itself perfectly clean, no serious mud ball trouble should develop.

Summary

1. Percentage sand expansion by depth, determined on a clean sand basis, gives a true indication of the behavior of the rapid filter sand layer during backwash.

2. For uniformly effective washing of any given filter the sand rise should be kept constant, at whatever height experiment shows will yield best filter cleaning results.

3. Sand expansion is greater under the following conditions: higher wash velocity, colder water, lowered sand density (due to coating of grains) finer sand and more angular sand.

4. Frictional effect between water and sand surfaces governs expansion in all cases.

5. Dirt is removed from sand surfaces by abrasion and when friction between water and dirt surfaces overcomes adhesive force between dirt and sand.

6. Frictional effect is greater at higher wash velocities. Relatively high wash rates are applicable only to clean sand of coarse sizing.

7. Maintenance of clean filters by ordinary backwash procedure requires the adoption of the coarsest possible sand, consistent with satisfactory filtration results.

8. Mud balls do not present a serious problem in the case of coarse sand filters washed at high velocities, because under these conditions, those that form remain on, or very close to the filter sand surface.

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The Fundamentals of a Properly Designed and Properly Operating Filter

By Carl J. Lauter

A FILTER system may be divided into three major parts, each of which is fundamental and essential to the successful operation of the unit as a whole: (1) the strainer or underdrain system, (2) the layer proper or medium for filtration, and (3) the reconditioning or wash system.

A filter is intended to filter or clarify a definite volume of water or solution in a definite time at a definite unit area rate. This rate has been more or less accepted by water works engineers to be 2 gpm. per sq.ft. for ordinary gravity filters. Recently, however, there have been tendencies to increase this by 50 per cent with little change in design.

A properly treated water is assumed for the successful operation of any filtration plant, leaving only the three elements for discussion, namely, strainer, filter body and wash system.

Strainer System

These are of various design and might be classified in three general groups which in order of appearance are: (1) pipe laterals, (2) valleys and concrete ridges and (3) false bottoms.

In the pipe laterals we have the cast-iron, steel and wrought-iron pipes, first with sprinkler heads and nozzles and later simply with drilled holes, lined or unlined, and with holes set at various positions. Asbestos-cement pipe is also included in this group. Pressures in these lines are generally high and ratio of opening to layer area is generally about 0.3 per cent.

With the ridge and concrete valleys there were the perforated metal plates or inverted pyramid over the ridges, with perhaps the same opening ratios.

False bottoms are more recent in adoption, including steel plate tops with many holes, inverted pyramids fitted with series of porcelain balls, or having porous plate tops over the water compartment, made up of various ma-

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terials and advanced primarily to eliminate the gravel layers in the filter layer proper.

Slat bottoms, a special adaption of false bottoms, embarked upon the idea of low water velocities with very large opening ratio. This type is, however, rapidly passing out of the picture.

Any of these types of strainer systems can be applied to any filter but such will involve definite arrangement and grading of the filter medium. There is also a wide cost differential between the various types. The strainers must be equally distributed over the entire filter so that there will be no dead spots, and the collecting system must be adequate to carry off the maximum amount of water at the chosen rate of filtration when operating at the desired head.

Filter Body

This, the filter layer proper, is dependent on the type of strainer system chosen and upon the type of water or material to be filtered. In ordinary practice, sand or a combination of sand and gravel has been the most universal medium. Charcoal, anthracite, calcium carbonate, and in industrial filters, the special zeolites are the other principal mediums employed.

Depth of layers and fineness of material are important factors and are often determined by the type of flocculated matter to be filtered out.

Methods of supporting the medium of the underdrain system chosen must be carefully planned. Those underdrains with large openings must have overlying gravel graded down through several gradations, which in turn will support the finer filter medium.

The active working area of any filter is the surface layer, or the first inch or so. The depth of penetration of floc into the surface is dependent on the rate of filtration employed and the size and nature of material to be filtered out.

When there is a tendency to lengthen runs to save washing, the lowest layer of the medium will become involved in the filter job. A deep filter may therefore allow longer runs but may become fouled sooner than a shallow one that is cleaned more often.

A thin layer of fine material on the surface of a shallow filter may be more desirable than a deep but more uniformly graded filter. The former, however, will clog sooner and may even be washed so hard that the fines are lost. Therefore, a fairly uniform gradation will perhaps be the most practical and of a depth to warrant good runs and take care of occasional poor flocculation and penetration of floc. Choice of filter material, and depth and fineness of same, are, therefore, very essential in determining the nature of the effluent. Proper choice of the filter material may often counteract defects in the other two factors—strainer and wash system.

Filter Washing System

The third part of a filter system is its washing or cleansing mechanism. Since a filter strains out the flocculated matter on the surface first, it is evident that a layer which will gradually cause a decreased flow is built up. This drop in flow will eventually proceed so far that the water will either stop entirely or, in a pressure system, the surface layer may rupture, causing material to be forced down into and through the filter layer.

To recondition a filter, the surface layer may be removed and cleaned or even broken up. This is the practice in a slow sand system. On rapid sand filters or pressure filters, sand removal is not practical since rate of filtration averages 40 times as high and washing must be 40 times as frequent as the slow sand system.

Backwashing or forcing clean water in reverse direction of filtration is, therefore, the practice. This rate of backwash is a very important detail and varies according to filter mediums, size and volume of material and also according to the nature of coagulated matter.

The function of the washwater is to cleanse the filter medium of the adhering floc; in a collecting trough system, the force is upward and out of the filter proper. The velocity of the wash must not be great enough to wash out the filter medium but it must disperse it so that the particles will strike each other and thereby scour themselves clean of the adhering coagulative suspended matter that was filtered out of the water.

This expansion and rate of upward velocity of wash water constitute a highly argumentative topic and two theories are presented: one recommends a very high expansion and the other a low one.

Size of filter particles plays an important role in the determination of the wash rate. If a filter is composed of large grain particles, then a high wash velocity is needed to cause the particles to be projected upward so they can scour themselves. With a fine medium, the same high velocity will cause a wide dispersion of particles and there will be less particle impact and less scouring action than with a lower wash velocity. Thus, rate is dependent on the particles' size and weight.

Assuming that a satisfactory vertical rise has been established, it is, however, essential that this rate be uniformly distributed over the entire filter. If a filter washes well in some spots and there is less or no washing in other places, it is evident that these weak washing areas will eventually clog tight and spread their influence over a larger area. Subsequently, the filter will become furrowed with ridges and will finally have to be entirely rebuilt. If, however, a filter is perfectly designed in this regard, and all areas get equal wash, it still does not follow that a filter will always stay clean.

There must be sufficient time allowed for a wash to push out all the adhering floc and the freeboard or distance from sand to filter gutter must not be so great that the removed particles will not reach the gutter lips.

If a filter can be set up so that there is uniform upward wash at all points and all particles are removed, then all will be solved; however, this is a condition that is seldom met. Temperature changes cause all sorts of variations. In summer, it takes almost twice as much vertical rise to give the same amount of wash to dispel floc as it does in winter. This is due to difference in viscosity of the water. As soon as the loosened floc particles are not removed, they begin to ball up on the surface and these balls no longer rise to the gutter with what at first was an ample wash velocity. By removing these balls as fast as they form, this difficulty will be solved.

In the early circular type of filters, this was done by dragging chains and rakes over the surface during the wash period. These rakes broke up the surface and greatly assisted in keeping the filter free from mud balls.

Water jets on the surface by hosing are helpful but time-consuming and not always well directed. An auxiliary manifold system of surface wash, introducing a series of jets in a horizontal plane at relatively high nozzle velocity through small openings spaced 6 to 10 in. apart, is now solving the mud ball problem.

This additional equipment is the latest step in completion of a wash and it is destined to be a vital factor in the design of a filter. However, this agent alone, with a poor underdrain system and too much freeboard or too much sand expansion, will not keep a filter clean.

No surface grid will ever correct a faulty underdrain system, but the author believes a perfect underdrain with proper rate of wash and freeboard and with correct choice of medium may and will operate successfully without a surface grid.

A properly operating filter system must therefore have the following factors:

1. It must have a properly treated water.
2. It must operate at a uniform and proper rate of flow.
3. It must have a medium suitable for the water to be filtered and the medium must be arranged with reference to type of bottom.
4. Wash must be uniform and flow of water in gutters must be equal at all points.
5. Freeboard must be as low as possible to allow loosened floc to go over and yet not too low to permit loss of filter material.
6. Rate of wash must not be too great and so disperse material too widely.
7. The surface should have an independent system of cleaning that can be used when needed, but not as a substitute for the upward wash system.

Some Observations on Filters

By F. R. Georgia

THE present Cornell University Filter Plant was placed in operation early in 1939. It contains three 12- by 15-ft. filters, each rated at 500,000 gpd. As originally constructed these filters had conventional pipe grid distribution systems and contained 18 in. of graded gravel and 30 in. of sand with an effective size of 0.45 mm.

Serious corrosion of the laterals of the pipe grid system occurred and resulted eventually in such unevenness of wash that rebuilding of the filters became necessary. Filters 1 and 2 had been rebuilt using the original design before the writer was placed in charge of the plant in 1938. At that time Filter 3 had not been rebuilt and was in very bad shape, and Filter 1 was not much better.

Filter 3 was rebuilt in 1939 using a Wagner bottom. This construction has given good distribution of wash water, but the filter has shown marked air-binding in the warm months, with resultant shortening of filter runs. The rather porous cement of the Wagner blocks seems to catalyze the liberation of dissolved air from the water to a very much greater degree than occurs in the other filters.

When the filter was rebuilt, the $2\frac{1}{2}$-in. cast-iron laterals were found to be badly corroded. A study of the laterals showed that corrosion started at the point of contact where gravel stones were wedged under the laterals. Such stones were coated with heavy iron rust deposits and the pitting of the laterals was extensive enough in many cases to result in holes of 1 in. or more in diameter. The orifice holes in the laterals were simple $\frac{5}{16}$-in., drilled holes. They showed no appreciable corrosion except as they might by chance be included in an area of corrosion as above described. Some of the laterals are shown in Fig. 1.

Filter 1 also needed rebuilding. In an attempt to get away from the difficulties experienced with other types of construction it was decided to

A contribution by Dr. F. R. Georgia, Cornell University Filter Plant, Forest Home, Ithaca, N.Y.

use porous plates, made by the Norton Company, for the bottom, to use anthracite (Anthrafilt) as the filtering medium, and to install a Palmer Agitator to assist in the control of mud balls.

Construction of Filter

Some of the structural features of this filter are different from others that have been described and they are, therefore, presented here in some detail. The general layout is essentially that furnished by Prof. T. R. Camp, of the Massachusetts Institute of Technology, as consultant for the Norton Company.

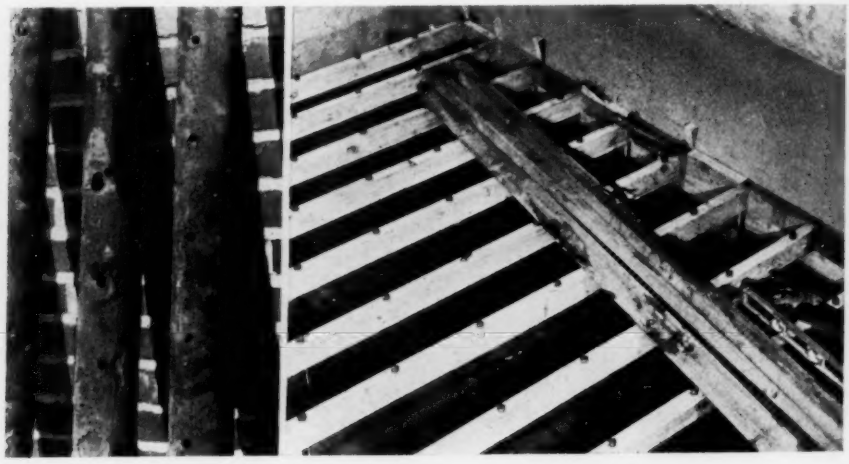

FIG. 1 FIG. 2

FIG. 1. Corroded Laterals Removed From Filter 3

FIG. 2. Template With Everdur Studs in Place; prior to pouring concrete slab. The spacing of the template pieces was maintained by nailing 2-×4-in. pieces across them in two places.

The laterals in the old filter connected through tees to a central concrete trough running the length of the filter below the floor level. The concrete slab covering the trough was broken out and replaced with a slab having fifteen $2\frac{1}{4}$-in. holes spaced on 12-in. centers. These holes serve to distribute wash water and also act as collectors for the filtered water.

Everdur anchor bolts or studs for the support of the porous plates were set in a 4-in. reinforced concrete slab poured over the whole filter bottom, except that the fifteen holes referred to above were extended through it. The studs were held in place while the slab was poured by a carefully constructed template (Fig. 2). Considerable care was required at this point in order to obtain accurate spacing of the studs.

The next step was to acid-proof the floor and walls of the filter with a

bituminous coating (Bitumastic Enamel) as a precaution against attack if it becomes necessary to clean the plates with acid.

An enamel-coated $\frac{3}{16}$-in. steel plate, 18 in. wide, and running the length of the filter, was fastened to the studs 2 in. above the holes from the central trough. The purpose of this plate is to break up the velocity head of the wash water entering the filter and thus get better wash water distribution (Fig. 3).

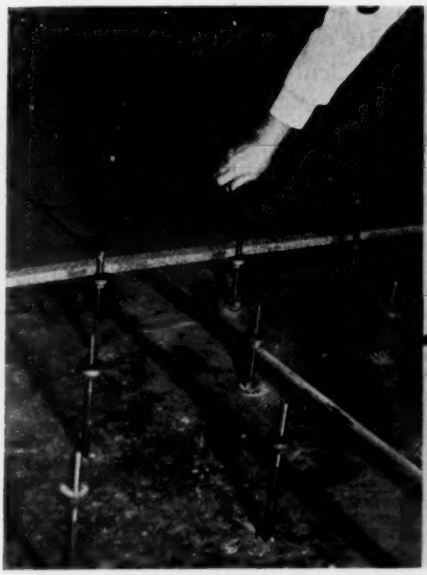

FIG. 3

FIG. 4

FIG. 3. Close-up of Bottom; showing method of support, steel baffle plate, Everdur acid cleaning pipe, rabbet on plates, and calking.

FIG. 4. Similar to Fig. 3; but taken from above. Palmer Agitator is shown

A piping system of $\frac{3}{4}$-in. Everdur with perforated laterals was placed in the filter under the plates as a means for introducing acid below the plates, if such is required for cleaning (Figs. 3 and 4).

The plates were then set and calked. The tops of the plates were 8 in. above the filter floor and each plate was supported at three points by the Everdur studs. On each stud below the plate was a nut, a heavy tapped washer which served as a lock nut, and a sponge rubber washer. Above the plates there was another sponge rubber washer, an ordinary light weight washer and a nut. The studs were $\frac{1}{2}$ in. and the washers $1\frac{1}{2}$ in. in diameter.

The Palmer Agitator was installed before the plates were set, in order to avoid possible injury to the plates by accidental dropping of tools (Figs. 4 and 6).

The Porous Plates

The nominal dimensions of plates for use in filter bottoms are 12 in. square by 1½-in. thick. It is quite difficult, however, to manufacture plates to exact dimensions. Oversized plates are almost impossible to use, and if they are too much under size the joint will be too wide. Tolerances in use seem to have been 12 in. plus or minus ⅛ in. for the side dimensions. The Cornell plates were contracted for with a tolerance on the 12-in. sides of plus 0 and minus ⅛ in. When the plates arrived from the Norton Company it was found that they had been made slightly over size and then ground to exactly 12 in. The resulting fit was so excellent that a slight increase in cost would be justified in order to adopt this method as standard in the production of plates for filter bottoms.

Such perfectly fitting plates would be difficult to joint but for the fact that, following a suggestion from Henry T. Hotchkiss Jr., of Larchmont, N. Y., the plates were provided with a rabbet all around the top edge. The rabbet was such that, when two plates were placed together, a groove was formed ½ in. deep and ⅛ in. wide at the bottom and ¼ in. wide at the top.

The advantages of the rabbet are so great as to offset entirely any increased manufacturing costs. The rabbet and three-point method of support combine to make it necessary to provide plates with special cutouts for he corners, ends, and sides of the filter. The rabbet is shown in Fig. 3.

Cutouts to take the ½-in. Everdur studs were on a ⅜-in. radius for circular and semicircular cutouts, and where studs came at corners of plates the plates were cut off at a 45-deg. angle, $\frac{7}{16}$ in. from the corners.

The three-point method of support not only prevented the plates from being placed under strain when the nuts were run down on them, but also greatly facilitated leveling the plates as they were set. The completed bottom was quite firm and stable. No fears need be entertained as to the strength of this type of construction. Supporting the plates on studs results in the covering of less plate area than in other methods, such as the use of concrete pieces.

No difficulty was experienced in setting the plates except around the edges where unevenness of the concrete walls and variations of the filter tank from exact dimensions made it necessary to cut a groove in the walls.

The joints and edges were calked with a marine calking compound applied with an ordinary calking gun. The only difficulty with the filter thus far has resulted from blowing this calking around the edges at places where the joint was too thick. This defect was repaired by two men in one day. The anthracite was shoveled back from one side, the calking removed, and the joint filled with cement. The anthracite was backfilled and the opera-

tion carried completely around the filter. This operation should be compared with a similar one in a filter of classified sand and gravel. The calking in the joints between the plates is quite soft but has held in place. It seems, however, to take up considerable chlorine from the water. It would probably be better to pour such joints with hot phenol-free asphalt.

Piezometer Tubes

A piezometer tube was run from below the plates to a gage glass on one wall of the filter to measure the head loss through the plates and anthracite during washing. This tube is shown in the corner of the filter in Figs. 5 and 6.

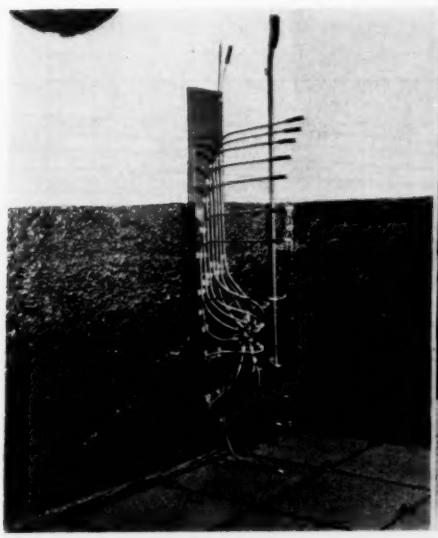

FIG. 5

FIG. 6

FIG. 5. Piezometer Tubes. The large one in the corner is the one shown in Fig. 6, while the others are for measuring losses of head in the bed during filter runs.

FIG. 6. The Completed Filter With Anthracite in Place; piezometer tube in corner of filter for measuring head losses during washing of filter; Everdur riser from acid cleaning system beside water supply line to Agitator.

A series of $\frac{1}{4}$-in. copper piezometer tubes was also placed in the filter to study the loss of head during filtration. These are shown in Fig. 5. One tube projects above the anthracite and serves to provide a reference point by indicating the water level on the filter. The next eleven tubes are spaced in the anthracite with the last tube directly on top of the plates. A thirteenth tube is inserted under the plates. The ends of

these tubes are protected by $\frac{1}{4}$-in. alundum thimbles joined to them by short rubber tubes. The tubes connect to gage glasses in the filter plant pump room.

The filtering medium is a 36-in. layer of anthracite (Anthrafilt) having an effective size of 0.70 to 0.72 mm., and a uniformity coefficient of less than 1.60. The freeboard from the top of the anthracite to the tops of the troughs is 25 in.

The Palmer Agitator was supported from a 2-in. nipple welded to a length of 3-in., extra heavy pipe which was set into the filter walls. The extra heavy pipe was used because the wash troughs had been supported in the center by pipes from the filter floor, and if this support is found to be desirable it can be provided from the extra heavy pipe. The Agitator is shown in Figs. 4 and 6.

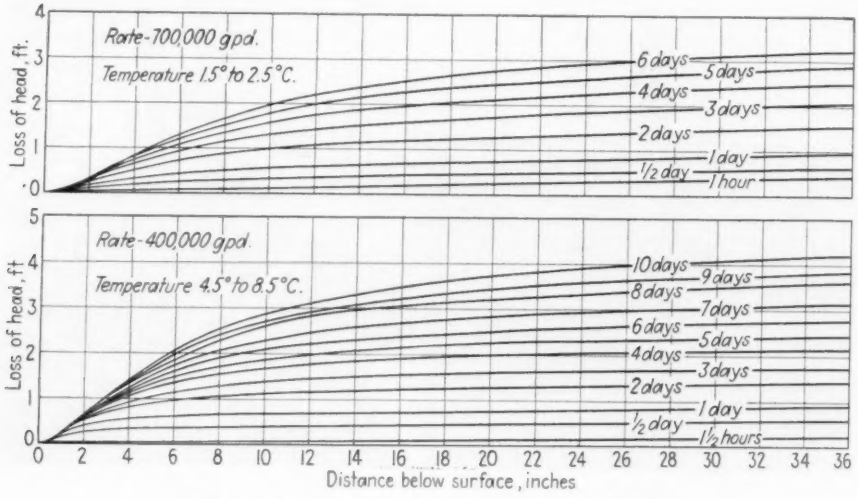

FIG. 7. Loss of Head Curves for Two Runs

Results of Operation

The filter has been operated for over a year at rates ranging from 350,000 to 700,000 gpd. Some runs have been made exceeding 300 hr. in length before washing.

Exact comparisons with the other filters have been impossible since the rate of operation of the plant must be adjusted to meet consumption. Thus, while the rate of one filter might be held constant for a run, it would be necessary to adjust the rate of the other filter in operation from time to time.

It is possible to state in general terms, however, that lengths of runs of Filter 1 have been materially longer than for the other two filters under similar conditions. Somewhat more water has been required for each washing of the filter, but this has been more than compensated for by the longer runs and consequent greater production of water. The loss of head builds up much more slowly in this filter and does not reach much over 4 ft. before termination of a run. The other filters usually run to a 9-ft. loss of head.

Loss of head studies have been made on a number of runs at different rates of operation. Typical sets of curves are shown in Fig. 7 for a run made at 400,000 gpd. and for one at 700,000 gpd. As would be expected, most of the loss of head takes place in the upper portion of the filter and for the anthracite used the greater part of the loss of head occurs in the top 12 in., with but slight increases below that depth. During a run some contraction of the anthracite takes place. This may be enough to uncover the first piezometer tube located $\frac{1}{2}$ in. below the surface of the anthracite at the start of a run. This shows up on the curves by what amounts to a shift of the origin along the x-axis to the right.

Some initial clogging of the plates occurred at the start and is probably to be ascribed to some penetration of anthracite into the larger pores of the plates. The initial loss of head through the plates and anthracite was 1.1 ft., with a wash rate of 15 in. vertical rise per minute and a temperature of 2°C. The loss of head at present is about 2.2 ft. with a wash rate of 30 in. vertical rise per minute and a temperature of 15°C.

The filter was deliberately operated for long periods to see what would happen. While the effluent at the end of a 300-hr. run may be quite satisfactory and show almost no turbidity in a Baylis turbidimeter, it is not believed to be good practice to put this much load on the filter. When this has been done, some consolidation of the anthracite has occurred along the filter walls and larger amounts of wash water have been required to break this up. Runs have now been reduced to one week and may be cut even more if future operation makes this seem desirable. The water applied to the filters has usually carried a floc turbidity under 5 ppm.

The Palmer Agitator has been quite useful. In the other two filters it has been necessary to remove mud balls from time to time in order to keep them in condition. This has not been necessary in the anthracite filter with the agitator.

The controller equipment on the filter has not permitted operation at more than 700,000 gpd. which means a rate of 2.8 gal. per sq.ft. per min. Results at this rate were quite satisfactory and there is no reason for believing that this could not be exceeded with properly coagulated and settled water. It is quite possible that shorter runs at higher rates are more de-

sirable than longer runs at lower rates as far as the effect on the condition of a filter is concerned.

Conclusions

The results after more than a year of operation of a filter with a bottom of Norton porous plates, an Anthrafilt filter layer, and a Palmer Agitator have been considerably better than those from two sand filters of more conventional construction.

Clogging of the plates has been very slight up to the present.

A filter of this type, containing no classification of material, permits repairs and inspections to be made very readily and without the heavy cost of reclassification of sand and gravel.

Present Status of Tests for Organic Pollution Loads

By A. M. Buswell and E. C. Dunlop

THE first tests developed for determining the sanitary quality of water were based on chemical determinations of the organic load. The permanganate oxygen test proposed by Tidy (1) and the nitrogen tests put forth by Frankland (2) came into prominence about the middle of the last century and were first extensively reviewed in this country by Mallet's committee (3). Although the nitrogen tests were more popular at first, the trend has been toward liquid or wet combustion, and a relatively enormous amount of literature on the subject of wet combustion methods has accumulated. The most popular oxidizing agent was and still is potassium permanganate because of the simplicity of its application. This field was summarized in 1937 by Burtle and Buswell (4) who recommended chromic acid as the most satisfactory reagent for producing complete oxidation. Potassium persulfate is another reagent which has remained in favor, and, more recently, the use of potassium iodate has been recommended.

These reagents all involve the wet oxidization of the organic matter when a known amount of the oxidizing agent is added. Results are obtained by titrating the excess with some suitable reducing agent, subtracting from the amount originally added and calculating as oxygen demand.

Another chemical reagent, which really measures the organic load but is ordinarily not classified with the oxygen demand reagents, is chlorine. This reagent is now so universally used in water treatment and is gaining so rapidly in use in sewage treatment that we are inclined to class the chlorine demand test along with the other chemical oxidizing agents.

There are two problems connected with the chemical methods of determining oxidizable organic load: first, it is difficult to arrange proper conditions so that all of the oxidizable organic matter reacts with the oxidizing agent; and, second, it is not possible to determine the products of oxidation.

A contribution by A. M. Buswell, Chief, and E. C. Dunlop, Asst. Chemist, State Water Survey Div., Urbana, Ill.

If we had an analytical method capable of detecting accurately sufficiently small amounts of carbon dioxide it would be possible to carry on these wet combustions by the determination of the CO_2 produced, as is done where larger amounts of carbonaceous materials are determined.

A second method for determining oxygen for estimating organic matter is by exposure of the liquid to a confined volume of air or oxygen and measuring either the decrease in pressure or decrease in volume due to the absorption of oxygen. This, to the writers, is the most attractive method from a theoretical standpoint, but mechanical difficulties have been rather great. Numerous procedures are described, dating at least as far back as Adeney (5). Burtle and Buswell (4) describe successful application of this method using the "Odeeometer," an apparatus designed by Nordell. The principal objection to this equipment is its cost.

A third method is the well-known biochemical oxygen demand test described in 1908 in the reports of the British Royal Commission on sewage disposal, and more recently summarized by Theriault (6). As is well known, the test consists of adding a known amount of polluted liquid to a known volume of diluting water of predetermined oxygen concentration. Incubation at a suitable temperature and for a suitable length of time precedes the determination of residual oxygen. The amount remaining subtracted from the original oxygen content is the B.O.D. This test like the direct absorption test has the advantage of duplicating, to a degree at least, the natural conditions under which organic material is oxidized through the activity of micro-organisms. A variation of this test is the methylene blue or putrescibility test which involves the addition of a color indicator which will show zero oxygen content. Another variation, now fallen into disuse, involved the addition of nitrates to the dilution water, the amount of nitrate reduction constituting the measure of oxidizable organic matter.

The B.O.D. test presents two problems: first, the question of a suitable dilution water which will furnish a favorable medium for bacterial growth; and, second, the development of an analytical method for determining dissolved oxygen in the presence of such possibly interfering substances as nitrates and nitrites, ferric ion, etc. The test, as originally proposed, advised using water from the stream into which the effluent was to be discharged as a diluting water and this seems to be a preferred method where results on a single plant effluent are desired. It is of course utterly impracticable where samples from different localities are examined in a central laboratory. At an early date distilled water was found to be unsuitable and even apparently bacteriostatic. The recent studies of these problems will be given in the following review.

A fourth method depending on absorption in the ultraviolet has recently been suggested (7). This method may find application in connection with

the detection of certain specific and important compounds. It does not appear to be generally applicable.

Chemical Oxidizing Agents

Since Burtle and Buswell's paper, in which they recommend the use of a CrO_3-H_2SO_4-H_3PO_4 mixture as an oxidizing agent, several other abstracts are available on other methods. H. Ivekovic (8) has restated that oxidization with permanganate is insufficient to determine the organic matter in water, as the permanganate does not react with all organic material. He includes the chlorine demand in connection with the permanganate demand. Nitrites interfere with the determination of the chlorine number by Froboese's method. From the chlorine number, however, the permanganate demand and the fluorescence in the ultraviolet and the nature and amount of organic impurities can be estimated. If all three values are high it indicates recent pollution. When the chlorine number is higher than the permanganate demand, complex nitrogen compounds are present. If the permanganate number is high, the chlorine number low, and the ultraviolet fluorescence strong, it points to vegetable matter or humic acids in relatively fresh condition.

Froboese (9) defines the chlorine number as the amount of chlorine, expressed in milligrams, that is required to satisfy the chlorine demand of one liter of the water or waste tested. He states that the chlorine number and the permanganate number in general show similarities, but later points out large variations. Keiser (10), however, has found that the chlorine demand of ground water gives valuable information concerning the types of organic matter present, but that the ratio of the chlorine demand to the oxygen demand, determined by the permanganate method, shows no correlation.

Even though the chlorine demand is not an absolute measure of the organic pollution, it is also well known that the permanganate demand is not absolute, and since so many waste disposal plants employ chlorine in their treatment, it may be useful to use the chlorine demand as a test for the organic pollution. This appears more promising with the recent development (11, 12) of better controls for regulating and determining the residual chlorine.

Dzyadzio (13) has suggested the use of KIO_3-H_2SO_4 for determining true oxygen consumption of sewage. The method is to reflux (200°C) the sample with KIO_3-H_2SO_4 until oxidization is complete (when evolution of I_2 ceases) and then to determine the excess KIO_3. A blank is run. Fourteen organic preparations were determined, the organic material being oxidized 100 per cent and the error not exceeding 2–3 per cent.

H. O. Halvorson (14) and one of his co-workers have also found that iodic acid is a good oxidizing agent for organic material. Halvorson states

that iodic acid will oxidize all the organic matter completely, but it will not oxidize ammonia. After the oxidization, however, the ammonia can be distilled off and determined. The oxygen consumption does not check exactly with the B.O.D. (either 5- or 20-day) determinations as would be expected, but the results do show a correlation. He reports they have obtained excellent checks in replicate determinations for the oxygen consumed.

Oxidation without heat by alkaline-KI starch solution with the addition of thiosulfate has been recommended (15) to replace the permanganate oxygen demand test. The method is indicated to be applicable to well waters, tap waters or river waters.

Biochemical Method—Dilution Water

The dilution B.O.D. method which is the standard adopted in *Standard Methods* (16) has been considered by numerous authors both from the standpoint of dilution water and method of determining the remaining oxygen.

Lea and Nichols (17) report that some organic materials (glucose) when diluted with plain bicarbonate dilution water and inoculated with sewage organisms gave, on the average, only about one-eighth as great a B.O.D. as when the same diluting water was supplemented with minute amounts of mineral salts. They carried out an investigation in which they analyzed for phosphorus and nitrogen in the B.O.D. mixtures and have recommended a dilution water as follows:

$(NH_4)_2SO_4$	2.5 ppm.
$Ca_3(PO_4)_2$	0.01 ppm.
$MgSO_4 \cdot 7\ H_2O$	0.01 ppm.
KH_2PO_4	0.10 ppm.
$NaHCO_3$	300. ppm.

The B.O.D. results for wastes which were low in phosphorus and nitrogen showed a variation, depending on whether the plain or the supplemented dilution water was used. For wastes which contain available nitrogen and phosphorus, however, the B.O.D. values were consistent using either diluting water.

Analysis of the water in a number of streams into which wastes are dumped showed that they contained sufficient phosphorus and nitrogen. Therefore, the authors are advocating the supplemented dilution water, because it is generally desired to measure the B.O.D. of all wastes by the same yardstick under identical growth conditions regardless of the kind of waste tested (18, 19).

In a paper, "Uses and Abuses of Biochemical Oxygen Demand," Nichols (20) again recommends the use of the above-mentioned supplemented

dilution water. Organic wastes high in nitrogenous constituents provide normal conditions for bacterial action but the 5-day B.O.D. as carried out shows no usage of oxygen in oxidizing the nitrogen and only 65–70 per cent of the carbonaceous material is oxidized. Further mention of this point will be made.

Several papers have been published in regard to the effect of dilution water on the B.O.D. of industrial wastes. One of the most recent of these is by George Martin and E. P. Miller (21) who have studied sulfite liquor wastes. In this work they use the river water into which the waste is to be dumped as the dilution water. This is recommended in order to get an exact reproduction of what takes place in the stream itself. The water should be aged (keeping it aerated) sufficiently to satisfy most of the B.O.D. originally present. It should also be seeded with fresh water from the same source (10 ml./l.). Results showing the wide differences in B.OD.. are shown by their data:

Using standard bicarbonate dilution water:

Before treatment	3,162 ppm. 5-day B.O.D.
Treated effluent	548 ppm.

Using raw river water as dilution water:

Before treatment	24,200 ppm. 5-day B.O.D.
Treated effluent	18,500 ppm.

The bicarbonate water not only gave much lower results but was much more erratic, giving results that could not be checked on consecutive runs.

In this study of pollution by sulfite liquor wastes the authors found that it is not sufficient to draw conclusions based on any particular portion of the B.O.D. curve, that is, the 5-day B.O.D. may or may not be a large percentage of the total B.O.D. The only satisfactory method is to determine a ten- to twenty-day curve on the waste and to interpret the pollution load from this curve. To show some of the variations in the 5-day B.O.D. with various dilution water, a portion of their data on a sulfite waste is as follows:

Dilution Water	*5-Day B.O.D. (20°C)*
Wisconsin River	22,500 ppm.
Wisconsin River (fresh Fox River seed)	37,500 ppm.
Sturgeon Bay	27,500 ppm.
Green Bay	15,000 ppm.
Fox River	37,500 ppm.
Bicarbonate dilution water	5,500 ppm.

C. C. Ruchhoft (22) has given the report of a co-operative study of dilution water to be used in the 5-day B.O.D. determination. In this study three types of dilution water were used: the standard bicarbonate

dilution water as given in eighth edition of *Standard Methods* (16); the phosphate buffered (formula C) water, containing, in addition to the bicarbonate, $FeCl_3$, $CaCl_2$, $MgSO_4$, KH_2PO_4 and NaOH to adjust pH; and formula C water fortified with $(NH_4)_2SO_4$. More than 1,000 samples were compared, 10 laboratories contributing. $(NH_4)_2SO_4$ was found to have no effect on the relationship between the 5-day B.O.D. of the bicarbonate and the formula C diluted tests. It was therefore recommended as a source of nitrogen.

On the basis of this study it was concluded that the mineralized phosphate buffered dilution water is superior to the bicarbonate water for the determination of 5-day B.O.D. in sewage treatment practice when the efficiency of a treatment process is to be followed. The ammonia-supplemented mineralized phosphate buffered water is superior for the determination of B.O.D. on nitrogen-deficient waste and is entirely satisfactory for other types of pollution. The members of the committee making this test recommend that the nitrogen-supplemented phosphate-buffered water be adopted as standard and suggest that it be called the Theriault-Nichols dilution water.

Sawyer's results (23) on the B.O.D. of waste sulfite liquor-sewage mixtures are in agreement with the above report. He shows that, for sewage mixtures containing more than 2 per cent waste sulfite liquor, the supplemented dilution water should be used, while, for lighter loads, either the supplemented or standard bicarbonate dilution water gave satisfactory results.

Biochemical Method—Oxygen Determination

Barnett (24) has investigated the use of sodium azide in the Winkler method for the determination of dissolved oxygen. He proposes the use of the azide in the alkaline-iodide solution and gives comparative results using the Winkler (25), Rideal-Stewart (26), Ruchhoft (27), and the sodium azide in alkaline-iodide methods. The results with the alkaline-iodide-azide agree with the Ruchhoft method within experimental error. The Rideal-Stewart method gave low results and the Winkler method, high ones. From the data obtained, Barnett recommends the use of sodium azide as an ingredient of the alkaline-iodide Winkler reagent in the determination of dissolved oxygen in pollution tests where nitrites are present in objectionable amounts. The azide reacts with the nitrite to give nitrogen ($HNO_2 + HN_3 \rightarrow N_2O + N_2 + H_2O$).

O. R. Placak and C. C. Ruchhoft (28) have recently made a comparative study of the azide and Rideal-Stewart modifications of the Winkler method for determining dissolved oxygen in B.O.D. determinations. They compared the Rideal-Stewart (26), the Alsterberg (29) and a modi-

fied azide method. The latter consists of adding the azide to an acid solution. After standing ten minutes for removal of nitrite, as mentioned above, the manganous sulfate and alkaline-iodide are added, and the test is completed as usual.

All the tests were made on river waters and the results show that they are equally good for determining the B.O.D. in river pollution studies. The addition of the acid and azide as a preliminary step is advantageous in preventing oxidization and may be used when it is desirable to store the samples a short while or in transporting them to a central laboratory.

Another modification of the Winkler method has recently been discussed by S. Cohen and C. C. Ruchhoft (30). A procedure involving the addition of sulfamic acid along with the manganous sulfate and allowing time for nitrite removal before the alkaline-iodide is added was found to be satisfactory for determining the pollution of some waters. Sulfamic acid reacts with nitrites, forming nitrogen, sulfuric acid and H_2O—$NH_2SO_3H + HNO_2 \rightarrow H_2SO_4 + N_2 + H_2O$. The addition of acid and sulfamic acid was also found to be comparable to the acid-azide procedure for preserving samples for later dissolved oxygen tests. The sulfamic acid method is not recommended when suspensions of river mud, iron (>50 ppm.), sulfite wastes, or other oxidizing or reducing agents are present.

In recent years the polarograph (31–38) has been perfected until it seems to give accurate results in the determination of dissolved oxygen. The most recent paper on its development in connection with pollution is by Ingols (35, 36), in which he describes the determination of dissolved oxygen in activated sludge aeration tanks and in streams. The accuracy is fair. Dissolved salts (1,500 ppm. NaCl) produce negligible error (0.13 ppm.), and the presence of nitrates and nitrite introduces no error. After calibration, the instrument provides a rapid as well as accurate means of determining dissolved oxygen.

Aside from the possibility of continuous recording of the oxygen content of a stream, this instrument also suggests the possibility of the determination of residual oxygen throughout the B.O.D. incubation. An incomplete but indicative discussion by Otto H. Müller (39) on "Research With the Polarograph" gives reference to four authors (33, 40, 41, 42) who have measured oxygen concentration in solution with a polarograph by applying a fixed voltage (−0.5 v.) and noting the corresponding galvanometer deflections.

Spectroscopic Methods

In 1936, Demmering (43) gave a report concerning the application of absorption spectroanalysis to the investigation and control of contaminated

surface waters. The method seems very promising, but work here seems to indicate difficulties. Pure water is transparent throughout the ultraviolet region, which is the most important point, but some of the organic materials, which add to the pollution, absorb only in the vacuum ultraviolet, and no satisfactory procedure has as yet been found for the rapid determination of their absorption. In a study (7) of some sewage from three cities, the effluent from a sewage plant, using a chemical treatment, and a beer slop from ethyl alcohol fermentation, it has been found that the ultraviolet (2,300–4,000 Å) absorption decreases with a decrease in the B.O.D.

The absorption spectrum analysis method has its real value in determining the pollution due to organic materials which contain chromophore groups which show strong absorption in the ultraviolet region. In the case of mixtures of pure phenol and cresols, it is possible to determine them in concentration of 1 ppm. upward. A preliminary treatment for removing suspended solids and other interfering substances must be made in order to get accurate results. Therefore, the method is more applicable to the determination of a special type of material than to the total oxygen consumption of a waste containing all types of polluting materials.

Summary

Although far from ideal as a measure of organic load and still limited in applicability, the B.O.D. test still holds the center of the stage. Recent interest centers around the problem of a dilution water, with a trend in favor of the addition of phosphate as originally suggested by Theriault.

The direct absorption method has received some impetus through the development of the "Odeeometer."

The interference of nitrites with the dissolved oxygen determination may be avoided by either of two new reagents—sodium azide and sulfamic acid. An entirely new instrumental method of determining dissolved oxygen, that is, by means of the polarograph, has promising possibilities.

Studies of wet combustion methods have for the most part been along the line of refinements in technique in an attempt to improve accuracy and consistency. Although permanganate is still the most used chemical for routine work, because of the simplicity of the test, chromic acid or iodate are preferred where complete wet combustion is required.

The chlorine demand test deserves consideration as a parameter of pollution, and the remarkable accuracy of residual chlorine recorders suggests some useful applications where a continuous record is needed.

Spectroscopic methods especially in the ultraviolet have been suggested by some authors. They appear to be limited in applicability to the detection of certain specific substances in industrial wastes.

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Emergency Alternate Specifications
for
Sulfate of Alumina

Adopted by A.W.W.A. Board of Directors, June 25, 1942

DURING the period of war emergency, sulfate of alumina according to the following specifications shall be accepted as conforming to American Water Works Association Standard. Since these specifications may be subject to modification as conditions warrant, purchasers shall refer to "Current A.W.W.A. Emergency Alternate Specifications for Sulfate of Alumina" when obtaining material or making contracts. Whenever the present war emergency is over and/*or* controls imposed by the War Production Board or any national body having similar powers no longer govern production or use of bauxite or sulfate of alumina, the present A.W.W.A. Standard Specifications for Sulfate of Alumina shall apply.

Section 1—Chemical Requirements

1.1 The material shall be basic.

1.2 It shall contain not less than 14.00 per cent water soluble Al_2O_3.

1.3 It shall contain not more than 3.0 per cent iron as Fe_2O_3.

1.4 It shall contain not more than 15.0 per cent of material insoluble in distilled water.

Section 2—Size of Lumps or Grains

2.1 Lump sulfate of alumina shall range in size from not less than $\frac{3}{4}$ in. to not more than 3 in.

2.2 Ground sulfate of alumina for use in dry feeding machines shall be of such size that not less than 95 per cent shall pass a woven sieve having 10 meshes per lin.in. and 100 per cent shall pass a sieve having 4 meshes per lin.in.

Section 3—Packing and Shipment

3.1 Sulfate of alumina may be shipped in bulk, in bags of uniform weight or in barrels of uniform weight.

Section 4—Sampling and Testing

4.1 The composition of the sulfate of alumina shall be determined by analyzing samples taken promptly upon the arrival of the material at the point of consumption.

4.2 When sulfate of alumina is shipped in bulk, the sample shall be so taken that it will represent an average of all parts of the shipment from top to bottom, and shall not contain a disproportionate share of the top and bottom layers. It shall weigh at least 10 lb. and shall be crushed if necessary and mixed thoroughly and "quartered" to provide two 1-lb. samples, one of which shall be used for the immediate testing and the other of which shall be kept carefully sealed for use in a possible retest as provided hereinafter.

4.3 When shipped in packages at least 3 per cent of the number of packages shall be sampled. They shall be taken from various parts of the shipment, dumped, mixed and sampled as in the above paragraph.

4.4 Notice of dissatisfaction with a shipment based on these specifications must be in the hands of the consignor within ten days after the receipt of the shipment at the point of destination. If the consignor desires a retest, he shall notify the consignee within five days of receipt of the notice of complaint. The duplicate sample shall then be forwarded for a retest to some laboratory agreed upon by both parties. This retest shall be made at the expense of the consignor and the results accepted as final.

EDITORIAL NOTE: The A.W.W.A. Standard Specifications for Sulfate of Alumina referred to above are reproduced below. They are given here merely for reference as they will not apply until the war emergency is over.

Section 1—Chemical Requirements

1.1 The material shall be basic, shall contain not less than 17 per cent available water soluble alumina (Al_2O_3) and shall not contain more than 0.75 per cent iron (Fe_2O_3).

Section 2—Insoluble Matter

2.1 Sulfate of alumina from which the insoluble material has been removed shall contain not more than 0.5 per cent of material insoluble in distilled water.

2.2 Sulfate of alumina from which the insoluble material has not been removed shall contain not more than 7.5 per cent of material insoluble in distilled water.

Section 3—Size of Lumps or Grains

3.1 Lump sulfate of alumina shall range in size from $\frac{3}{4}$ to 3 in.

3.2 Ground sulfate of alumina for use in dry feeding machines shall be of such size that not less than 95 per cent shall pass a woven sieve having 10 meshes per lin.in., and 100 per cent shall pass a sieve having 4 meshes per lin.in.

Section 4—Packing and Shipment

4.1 Sulfate of alumina may be shipped in bulk, in bags of uniform weight or in barrels of uniform weight.

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American Standard
Manhole Frames and Covers
For Subsurface Structures

Foreword

STANDARDIZATION work on manhole frames and covers was started in 1924 under the procedure of the American Standards Association. The project was referred to this body by the Division of Simplified Practice, National Bureau of Standards, U.S. Department of Commerce, after a preliminary conference called by the latter had found that on account of its technical aspects the project was outside the scope of work of the Division. Upon advice of a special committee representative of American industry in this field, the A.S.A. Telephone Group (comprising the Bell Telephone System and the United States Independent Telephone Association), and the American Society of Civil Engineers, were invited to act as joint sponsors for the work.

The Committee found that the reasons for undertaking the standardization of manhole frames and covers were economic ones as there was no complaint that existing designs did not satisfactorily meet the requirements of the various services. The manufacturers engaged in producing manhole frames and covers claimed that there was an unnecessarily large number of slight variations in dimensions, which increased the stock of patterns and cost of manufacture and that there were no standards that could be adopted by either manufacturers or users who might not have their own design.

The Committee has, therefore, proceeded to prepare designs and specifications for manhole frames and covers of gray iron in the sizes commonly used and, in the case of manhole covers only, of sizes greater than those in general use, has included specifications for cast steel.

EDITOR'S NOTE: These design and dimensional specifications are published in the JOURNAL as a service to the water supply field. Their publication is not to be taken as evidence that no other design or dimension may be safely followed in water works practice. *Reprints of this standard are available from the American Standards Association, 29 West 39th Street, New York, N.Y.*

The designs now submitted for adoption as standards are believed by the Committee to be suitable for the use of those who have at present no satisfactory designs of their own or who may desire to avoid the additional expense that may be involved in the purchase of special patterns.

The organizations represented on the sectional committee are as follows: American Electric Railway Assn., American Foundrymen's Assn., American Gas Assn., American Railway Assn., American Society of Civil Engineers, American Society of Mechanical Engineers, American Society of Municipal Engineers, American Society for Testing Materials, American Water Works Assn., Canadian Engineering Standards Assn., Electric Light and Power Group, Gray Iron Founders Society, Inc., Malleable Iron Research Inst., National Electrical Manufacturers Assn., National Founders' Assn., National Safe Walkway Surface Code Com., New England Water Works Assn., Postal Telegraph Cable Co., Steel Founders' Society of America, Inc., A.S.A. Telephone Group, U.S. Dept. of Commerce—Bureau of Standards, U.S. Dept. of Commerce—Division of Simplified Practice, U.S. Independent Telephone Assn. and Western Union Telegraph Co.

Frank A. Marston served as official representative for the A.W.W.A. Other A.W.W.A. members who served on the sectional committee, officially representing other organizations, were: William W. Brush, William R. Conard, R. B. Morse (now deceased) and Homer Rupard (now deceased). L. B. Fish served as Chairman until 1937, when he resigned and S. C. Miller became Chairman. A. B. Campbell served as Secretary.

Explanatory Notes

Dimensional specifications for different types and sizes of manhole frames and for the corresponding manhole covers have been developed, as follows:

Straight type round base
Flared type round base
Flared type square base—height 10 in.
Flared type round base—shallow
Flared type square base—shallow
Flared type square base—height 7 in.
Flared type square base—light weight
Straight type square base
Straight type round base—for inner cover
Straight type square base—for inner cover
Straight type round base—shallow—flange midway between top and bottom—for inner cover
Straight type square base—shallow—flange midway between top and bottom—for inner cover
Shallow ring

The details upon which the designs for various classes of work are based are discussed separately below under the main headings: "Manhole Frames" and "Manhole Covers."

Manhole Frames

Shape of Opening. Round openings require less metal per unit area of opening than any other shape and avoid the possibility of covers dropping through the opening as is the case with square and rectangular covers. Also, round covers are easier to handle and less breakable in handling (no corners). Furthermore, machining of cover seats and covers is simplified.

Diameter of Opening in the Clear. The diameters of 22 in., 24 in., 27 in. and 30 in. for the opening in the clear of the frame, are suitable for the great majority of manholes. The diameters of 33 in., 36 in. and 42 in. were added to apply to cases where large objects have to be placed in manholes.

Height of Frame. The 7-in. height of frame for sewer, water, gas, steam and air manholes fits well with the present paving materials used. For the flared type of frame, the 10-in. height seemed preferable to obtain the necessary flare. For shallow types of frames, it was felt that the height should be kept to a minimum, and the $5\frac{5}{8}$-in. dimension was decided upon.

For the inner cover type of frame, a depth of 11 in. was selected to provide sufficient clearance between the top of the locking screw and the bottom of the cover, so as to prevent damage to the screw while the cover is being removed. Another reason is the desirability of providing space above the inner cover for any ice which might form in this location.

Thickness of Walls. A thickness of $\frac{5}{8}$ in. for the walls of all types of frames was considered satisfactory except in the case of the light-weight frames of Fig. 10* (wall thickness, $\frac{1}{2}$ in.), and the frames of Fig. 3, where ribs have been omitted (wall thickness, $\frac{3}{4}$ in.).

Shape of Outside Walls. The outside walls of all frames have been kept free, so far as practicable, from any projecting lips. Wherever a lip is required for holding the cover, it has been placed on the inside surface of the frame, if possible.

Width of Flange. A flange width of 4 in. seems to be adequate for most needs, but a note has been added making 5-in. and 6-in. widths optional where the type of construction may require this greater width. For shallow types of frames (Figs. 6, 7, 14 and 15), the flange width is 6 in. so that the bearing area will be about the same as for the corresponding full height

*Figures 3 through 22 are given at the close of the text of these specifications.

frames. The shallow type is generally used in regrading work, on the same manhole roof opening that was made for the deeper type of frame originally placed. Consequently, some of the flange bearing area is lost by overhanging the manhole roof opening.

Thickness of Flange. All flanges on the frames having ribs are $\frac{3}{4}$ in. thick where they join the walls and taper to $\frac{5}{8}$ in., except for the light weight frame, Fig. 10, where the dimensions are $\frac{1}{2}$ in. and $\frac{3}{8}$ in., respectively, and for the frames on Fig. 1 (which do not have ribs) where the dimensions are 1 in. and $\frac{3}{4}$ in., respectively.

Ribbing. Eight ribs are provided where necessary. They are $\frac{3}{4}$ in. thick where they join the flange, and taper to $\frac{1}{2}$ in., where molding practice permits. In other cases, the rib thickness is 1 in. at the wall, tapering to $\frac{1}{2}$ in. A hook hole is placed in each of four ribs to facilitate moving the frame.

Width of Cover Seat. A width of $\frac{3}{4}$ in. for the cover seat was considered satisfactory. In order to prevent the placing of a light-weight cover in a frame designed for vehicular traffic, the diameter of the opening in the clear of light-weight frames and the diameter of the corresponding cover were increased. For the light-weight frame of Fig. 10 and the shallow ring of Fig. 11, the diameter of the opening in the clear has been increased $\frac{3}{4}$ in. For the frames with 33-in., 36-in. and 42-in. openings, the width of the cover seat has been increased to 1 in. because of the greater diameter of the covers used in them.

Machining of Horizontal Face of Cover Seat. Machining the horizontal face of the cover seat and the corresponding face of the cover is proposed in all cases, to eliminate rocking of covers and to reduce wear. Moreover, this requirement automatically insures the use of a good grade of cast iron.

Machining of Vertical Face of Cover Seat. Machining of the vertical surfaces was decided upon to improve the fit between frames and covers, and to reduce wear resulting from clearance between vertical faces. The proposed difference in diameter between the cover and the opening in the frame, which receives it, is $\frac{1}{16}$ in. The closer fit obtained by machining the vertical surfaces will to a large extent prevent dirt from interfering with the fit of the cover on the horizontal part of the seat.

Width of Top. Because of heavy wear on frame tops, the minimum proposed width is 1 in. Where the size of frame requires a heavier casting, the maximum width is $1\frac{1}{2}$ in.

Depth of Lip Supporting Cover. Where the lip for supporting the cover is placed on the inside of the frame, it seemed desirable that the depth of this lip should be not less than $1\frac{3}{8}$ in.

Shape of Lip for Inner Cover. From a foundry standpoint, the flat rather than the rounded type of lip for supporting the inner cover is recommended. Also, this type is less likely to become damaged in service than the rounded type.

Molds. The closed sand mold should be used for manhole frames where uniformity of thickness and evenness of surface is desired. However, where the design of the frame is applicable and where the surface at the bottom of the flange will permit of unevenness such as when a frame is mounted on top of brick or concrete and grouted, manufacturers may use the open sand mold if this is agreed to by the purchaser.

Manhole Covers

Camber of Surface. Flat covers are recommended in all cases because they contribute to smooth-riding pavements and there has always been considerable question in regard to the value of a cambered manhole cover.

Thickness of Cover. Long experience indicates that covers $1\frac{3}{8}$ in. thick are adequate for those sizes where the diameter of opening directly under the cover does not exceed 30 in. For larger openings $1\frac{1}{2}$ in. are specified in the case of cast-iron covers. For covers not subject to vehicular loads, the thickness is $\frac{3}{4}$ in.

Ribbing. A combination of circular and radial ribbing is proposed for the underside of the covers. The radial ribs are meant also to relieve, as far as possible, cooling strains between the periphery of the cover and its center, while the circular ribs are meant to relieve tangential cooling stresses.

Ventilating Holes. Ventilating holes are necessary in covers for sewer work. Also, they are useful in removing sewer covers by means of crowbars or picks. On the other hand, omission of the holes tends to keep water as much as possible out of the manhole. Ventilating holes have therefore been shown on the drawings in dotted lines, and a note makes their provision optional for most of the cast-iron covers. For the cast steel covers for the 36-in. and 42-in. frames and the cast-iron covers shown in Fig. 20, a large number of holes are shown for ventilation but the number to be provided is made optional with the purchaser.

Hook Holes. Hook holes are proposed in every instance to facilitate the removal of covers. Two sets of hook holes, diametrically opposite, are proposed with each hole at least $1\frac{1}{2}$ in. wide at the edge of the cover, 1 in. deep on the top surface, and $1\frac{3}{4}$ in. deep on the underside of the cover. In the case of covers to be used by electric light and power interests (see next paragraph) a slightly different form of hook hole is recommended.

The double arrangement of holes enables one man to pry the cover up so that another man can place his hook in back of the circular rib, allowing the first man then to place his hook in a similar position so that together they can pull the cover laterally out of its seat.

Pattern for Top Cover. It is proposed that the pattern for the top of all manhole covers be the same where practicable and that any distinctive features of ownership or class of use appear in the circular space left in the center of the cover. Where this is done at present, the circular part of the pattern forming the center of the top of the cover is made removable so that the same pattern can be used with different letter designations. For the cast-steel covers of Figs. 21 and 22 and the cast-iron covers of Fig. 20, which are designed for electric light and power use, a different pattern must be used because of the many ventilating holes.

Machining of Covers. The edges of all covers and that part of the underside of all covers which rests on the cover seat are to be machined (see section on "Manhole Frames").

Inner Cover. The curved type of inner cover is proposed because this type has been found satisfactory over long periods of service.

Frames and Covers

Weights. Minimum and maximum weights for frames and covers are stated. In some cases actual foundry data were available for these weights. In other cases the computed weight is listed.

Specifications. In drafting the specifications, it has been the object of the subcommittee dealing with this part of the work to specify requirements which would insure serviceability and at the same time be so simple that they can be understood and met by any well organized foundry. While high-strength iron and special alloys are widely used for various products other than manhole frames and covers at the present time, and might also provide a satisfactory quality, at a cost, for the latter, there does not seem to be much of anything in the way of experience with manhole frames and covers made of such metals that can be drawn on in making recommendations at this time. It was felt, therefore, that a good grade of tough gray iron would meet most of the requirements and be much more readily obtainable at foundries in every section of the country and at a minimum cost. In the cases of covers for the 36-in. and 42-in. sizes of frames, carbon steel has been specified in order to reduce the weight.

1. Specifications for Gray-Iron Castings for Manhole Frames and Covers

(*Based on A.S.T.M. Specification A48-36*)

1.1—Basis of Purchase

By the piece, or by weight, as arranged by the purchaser.

1.2—General Requirements

1.2.1—All castings shall be made of clean, tough, gray cast iron. The castings shall be true to pattern and free from cracks, gas holes, flaws, blow holes, cold shuts, excessive shrinkage, or any defect which would interfere with the use of, or impair the serviceability of, the castings.

1.2.2—Castings shall be well cleaned before inspection by means of suitable wire brushes or by other approved process.

1.2.3—Surfaces of the castings shall be free from burnt-on sand and shall be reasonably smooth. Runners, risers, fins and other cast-on pieces shall be removed. Also, castings shall conform to whatever points may be specially agreed upon between manufacturer and purchaser.

1.2.4—Castings shall not be repaired, plugged or welded without permission from the inspector. Such permission will be given only when the defects are small and do not adversely affect the strength, use or machinability of the casting.

1.2.5—Castings shall not be painted unless so specified.

1.3—Physical Properties and Tests

1.3.1—Transverse Tests:

1.3.1a—The transverse test bars specified in Sec. 1.3.2a when placed horizontally upon supports 18 in. apart and tested under a centrally applied load, shall conform to the following minimum requirements:

Load at center, lb	2,000
Deflection at center, in	0.20

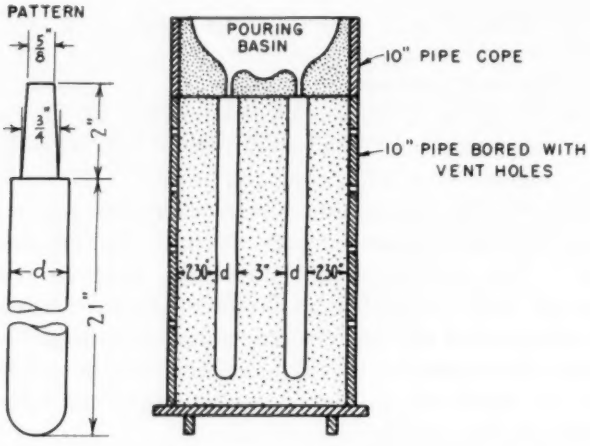
1.3.1b—The rate of application of the load shall be such that fracture is produced in not less than 20 sec.

1.3.2—Test Bars:

1.3.2a—Test bars shall be in accordance with the standard specifications for the 1.20-in. transverse test bar of the American Society for Testing Materials, A48-36. For convenience, a sketch of a simple mold is shown herewith in Fig. 1.

1.3.2b—Test bars shall be cast separately from the casting.

1.3.2c—Molding and Pouring Test Bars. Unless otherwise agreed upon by the manufacturer and the purchaser, test bars shall be made under the same sand conditions as the castings. The bars shall be poured from ladles of iron used to pour the castings. The test bars shall receive the



NOTE - THE DIMENSION "d" SHALL BE MADE SUCH THAT THE CASTING SHALL MEASURE APPROXIMATELY 1.20" IN DIAMETER AT THE MIDPOINT

FIG. 1. Mold for Arbitration Test Bar

same thermal treatment as the castings. In the case of heat treatment, the test bars shall be treated adjacent to the castings they represent.

1.3.2d—Transverse Test Procedure. The transverse test shall be made on the bar as cast, or as skin machined (providing in the latter case that the diameter is not reduced below the minimum sizes prescribed below in Table 1), with central loading between supports. Corrections shall be made for sizes of round bars as prescribed in Table 1. In case of slightly elliptical bars (maximum and minimum diameters both within the permissible variations prescribed in Table 1), loading shall be on the minimum diameter, and the correction factor shall be obtained as follows: Square the depth of the bar measured at the point of application of the original load,

multiply by the width, and divide the product by 1.728. A bar, whose diameters (maximum and minimum) vary by more than 0.050 in. in diameter of nominal sizes respectively, shall be considered a slightly elliptical bar.

1.3.2e—In all cases, controlling dimensions shall be the diameter of the bar at fracture.

1.3.2f—If a faulty or unsound test bar gives a result not in accordance with the specifications, the results shall be disregarded and another test made.

TABLE 1

Correction Factors for Transverse Test Bars

DIAMETER OF TEST BARS, IN.	CORRECTION FACTOR	
	Load	Deflection
1.10	0.770	1.091
1.11	0.791	1.081
1.12	0.813	1.071
1.13	0.835	1.062
1.14	0.857	1.053
1.15	0.880	1.043
1.16	0.903	1.034
1.17	0.927	1.026
1.18	0.951	1.017
1.19	0.975	1.009
1.20	1.000	1.000
1.21	1.025	0.992
1.22	1.051	0.984
1.23	1.077	0.976
1.24	1.103	0.968
1.25	1.130	0.960
1.26	1.158	0.952
1.27	1.185	0.945
1.28	1.214	0.938
1.29	1.242	0.930
1.30	1.271	0.923

1.3.3—Number of Tests:

1.3.3a—Two sets of two transverse test bars each shall be cast from each melt of 20 tons or less, one set from the first and the other set from the last iron going into the castings. Where the melt exceeds 20 tons, an additional set of two bars shall be cast for each additional 20 tons or fraction thereof. In case of a change of mixture during the melt, one set of two bars shall also be cast for every mixture other than the regular one—each set of two bars shall be cast in a single mold.

1.3.3b—All transverse test bars shall be tested as specified in Sec. 1.3.1a.

1.3.3c—Test Procedure. After removal from the flask and before being broken, the bars shall be marked or tagged so as to identify them with the heat or run that they represent. The pouring, removal from flask, marking and breaking shall be witnessed by the purchaser's representative unless otherwise agreed to by the purchaser. In this latter event he may accept the certified statement of the foundry covering tests and their results.

1.3.4—Requirements:

One transverse test bar of each set shall conform to the requirements specified in Sec. 1.3.1a; otherwise the castings represented by such bars shall be rejected.

1.3.5—Weights:

No casting under the minimum weight shown on the drawing will be accepted, and if the castings are purchased by weight (Sec. 1.1), no weight in any one casting exceeding the maximum shown on the drawing will be paid for. Each casting shall be weighed in the presence of the purchaser's representative unless otherwise agreed to by the purchaser.

1.4—Workmanship and Finish

1.4.1—Machining:

1.4.1a—All castings shall be commercially machinable.

1.4.1b—Where called for on drawings, the following portions of cover seats and covers shall be machined:

Frame—horizontal and vertical surfaces of cover seat.

Cover—under surface which rests upon the cover seat and the vertical surface which fits into the cover seat.

1.4.1c—After machining, it shall not be possible to rock any cover after it has been seated in any position in its associated frame.

1.4.1d—After any cover has been seated in any position in its associated frame, it is desired that the edge of the upper surface of the cover be flush with the upper surface of the frame. In those cases where such alignment is not obtained, the difference in level between any cover and the frame shall not exceed $\frac{1}{8}$ in. at any point and shall not exceed $\frac{1}{16}$ in. over a total of more than one-quarter of the circumference.

1.4.1e—It shall be possible to place each cover in any position in its associated frame without having more than $\frac{1}{8}$-in. side play in any direction between the cover and the frame.

1.4.2—Gages:

1.4.2a—The manufacturer shall provide suitable gages which shall conform to the contour and dimensions specified.

1.4.2b—In the case of frames that are to be used with cast-steel covers where limits are placed on the diameter of the opening in such frames, and on the diameter of the associated cover, the manufacturer shall provide suitable ring gages for determining conformity or non-conformity to the frame dimensions.

1.5—Locking Bars, Saddle Plates and Screws

1.5.1—Locking Bars and Saddle Plates:

1.5.1a—These parts shall be made of mild steel.

1.5.1b—They shall be free from imperfections that would interfere with the use of or impair the serviceability of these parts.

1.5.1c—Brittleness. Any section of any finished locking bar, when placed in contact with a smooth flat steel surface and struck sharply and vigorously with a 2-lb. hammer, shall show no evidence of fracture.

1.5.1d—Malleability. It shall be possible to bend any finished saddle plate when cold, flat upon itself without fracture of the steel. Saddle plates shall not be bent at the slot.

1.5.2—Screws:

1.5.2a—The screws shall be made of Monel metal.

1.5.2b—They shall fit the tapped hole in the locking bars so that they will neither have an undue amount of play nor be so tight that they cannot be turned down by hand.

1.6—Marking

Shall be as specified by the purchaser on the drawing.

1.7—Inspection

The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's plant which concern the manufacture of the castings ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the castings are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

2. Specifications for Carbon-Steel Castings for Manhole Covers When Steel Is Specified

(Based on A.S.T.M. Specification A87-36 Grade B)

2.1—Basis of Purchase

By weight or by piece, as arranged by the purchaser.

2.2—Manufacture

2.2.1—Process:

The steel shall be made by one or more of the following processes: open-hearth, electric-furnace, converter, or crucible.

2.2.2—Heat Treatment:

2.2.2a—A heat treatment either by normalizing or by full annealing at the option of the manufacturer shall be applied to all castings. Unless otherwise specified, all castings may be annealed one or more times, and may be given a supplementary heat treatment by tempering or drawing.

2.2.2b—All castings shall have been allowed to cool, after pouring, to a temperature below the critical range.

2.2.2c—Normalizing. The procedure for normalizing shall consist of heating the castings to the proper temperature above the critical range for the required time as a preliminary procedure for the ultimate refinement of the grain, and cooling in still air at room temperature.

2.2.2d—Full Annealing. The procedure for full annealing shall consist of heating the castings to the proper temperature above the critical range for the required time as a preliminary procedure for the ultimate refinement of the grain, and cooling slowly in the furnace. No casting so treated shall be removed from the furnace until the pyrometer indicates that the entire furnace charge has fallen to a temperature of 500°F. (260°C.) or lower.

2.2.2e—Tempering or Drawing. The procedure for tempering or drawing shall consist of heating such castings as have been normalized or full annealed, or have been given an authorized accelerated cooling, to a temperature below the critical range but not less than 400°F. (204°C.), and cooling by a suitable method to obtain the desired results.

2.2.2f—Annealing Lugs. For the purpose of determining the quality of annealing, at least two and not more than four annealing lugs shall be

cast on all castings weighing 150 lb. and over, also on such lighter castings as the purchaser or his inspector may require to be provided with such lugs. The locations of the annealing lugs shall be such that, when removed by the inspector, they shall indicate the effectiveness of the annealing treatment. The annealing lug shall be 1 in. in height, 1 in. in width, and $\frac{5}{8}$ in. in thickness where the lug joins the casting.

2.2.2g—Reannealing. If, in the opinion of the inspector, a casting is not properly annealed, he may at his option require the casting to be reannealed.

2.2.3—Temperature Control:

Furnace temperatures for heat treating shall be effectively controlled by pyrometers.

2.3—Chemical Composition

2.3.1—The steel shall conform to the following requirements as to chemical composition:

Manganese, maximum, per cent		0.85
Phosphorus, maximum, per cent		0.05
Sulfur, maximum, per cent	Acid	0.06
	Basic	0.05

2.3.2—Unless otherwise specified the contents of carbon and silicon shall be selected by the manufacturer to obtain the physical properties specified.

2.3.3—Ladle Analysis: An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus, sulfur and all other elements intentionally present in the steel. This analysis shall be made from drillings taken not less than $\frac{1}{4}$ in. beneath the surface of a test ingot made during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Sec. 2.3.1 and 2.3.2 and to such additional requirements as may have been agreed upon between the manufacturer and the purchaser.

2.3.4—Check Analysis: An analysis may be made by the purchaser from a broken tension test specimen or from a casting representing each melt. Drillings for analysis shall be taken not less than $\frac{1}{4}$ in. beneath the surface, and in such manner as not to impair the usefulness of any casting selected for such check analysis. The chemical composition thus determined shall conform to the requirements specified in Sec. 2.3.1 and 2.3.2 and to such additional requirements as may have been agreed upon between the manufacturer and the purchaser.

2.4—Tensile Requirements

The tensile requirements shall be as follows:

Tensile Strength, minimum, psi.,	70,000
Yield Point, minimum, psi.,	38,000
Elongation in 2 in., minimum, per cent,	24
Reduction of Area, minimum, per cent,	36

2.4.1—Tensile Properties:

2.4.1a—The tensile properties of steel used for castings shall be determined from the required number of specimens which have a 2-in. gage length, conforming to dimensions shown on Fig. 2.

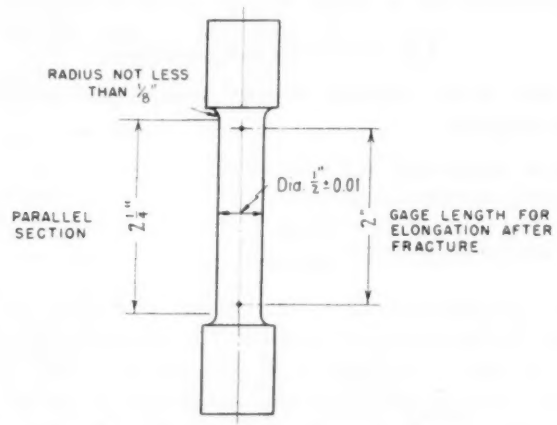

RADIUS NOT LESS THAN ⅛"
Dia. ½" ± 0.01
PARALLEL SECTION
2¼"
2"
GAGE LENGTH FOR ELONGATION AFTER FRACTURE
NOTE - THE GAGE LENGTH, PARALLEL SECTION, AND FILLETS SHALL BE AS SHOWN, BUT THE ENDS MAY BE OF ANY SHAPE TO FIT THE HOLDERS OF THE TESTING MACHINE IN SUCH A WAY THAT THE LOAD SHALL BE AXIAL.

FIG. 2. Tension Test Specimen

2.4.1b—Steel used for the castings shall conform to the requirements as to tensile properties prescribed in Sec. 2.4, above.

2.4.1c—The yield point shall be determined by the drop of the beam or halt in the gage of the testing machine, or by an extensometer, at a cross-head speed not to exceed ⅛ in. per min. The tensile strength shall be determined at a speed of head not to exceed 1½ in. per min.

2.4.2—Test Specimens:

2.4.2a—One or more test coupons sufficient in size and number to provide the required test specimens shall be cast attached to each casting weighing over 150 lb. The test coupons shall remain attached to the

castings throughout annealing and until the castings are presented for inspection. If the design of the casting is such that the test coupon cannot satisfactorily be attached to it, the coupon shall be attached to a runner connected with the casting. The locations of the test coupons and the method of casting them shall be subject to mutual agreement between the manufacturer and the purchaser's inspector. In the case of orders for castings weighing under 150 lb. each, the physical properties required in Sec. 2.4 shall be determined from an extra or spare test coupon cast attached to another casting from the same melt.

2.4.2b—When insufficient coupons have been cast to cover the tension test requirements of these specifications, a test specimen may be cut from a finished casting, at a location mutually agreed upon by the manufacturer and the purchaser's inspector, to cover any deficiency in the number of available coupons.

2.4.2c—Tension test specimens shall be machined by the manufacturer and shall conform to the dimensions shown in Fig. 2.

2.4.3—Number of Tests:

2.4.3a—At least one tension test shall be made from each melt.

2.4.3b—If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted from the same lot.

2.4.3c—If the percentage of elongation of any tension test specimen is less than that specified in Sec. 2.4 and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

2.4.3d—No part of these specifications shall operate to cause any one tension test to apply to more than 40 tons of castings as offered for inspection.

2.4.4—Retests:

If the results of the physical test for any lot do not conform to the requirements specified, the manufacturer may reanneal such lot, but not more than twice. The results of acceptable retests shall conform to the requirements prescribed in Sec. 2.4.

2.4.5—Weights:

No casting under the minimum weight shown on the drawing will be accepted, and if the castings are purchased by weight (Sec. 2.1) no weight in any one casting exceeding the maximum shown on the drawing will be paid for. Each casting shall be weighed in the presence of the purchaser's representative unless otherwise agreed to by the purchaser.

2.5—Workmanship and Finish

2.5.1—Gages:

2.5.1a—The manufacturer shall provide suitable gages which shall conform to the contour and dimensions specified.

2.5.1b—Where limits are placed on the cover diameter and on the corresponding opening in the frame intended for use with cast-steel covers, the manufacturer shall provide suitable ring gages for determining conformity or non-conformity to these cover dimensions. The opening between the surface and the gage at any point shall not exceed $\frac{1}{16}$ in.

2.5.2—Machining:

2.5.2a—Where called for on drawings, the following portions of cover seats and covers shall be machined:

Frame—Horizontal and vertical surfaces of cover seat.

Cover—Under surface which rests upon the cover seat and the vertical surface which fits into the cover seat.

2.5.3—Workmanship:

All castings shall be made in a workmanlike manner and shall conform substantially to the dimensions on drawings furnished by the purchaser before manufacture is started; or to the dimensions predicated by the pattern supplied by the purchaser, if no drawing has been provided.

2.5.4—Finish:

2.5.4a—The castings shall be free from injurious defects, and shall be satisfactorily cleaned for their intended use when offered for inspection.

2.5.4b—Repair by Welding. Defects that will not ultimately impair the strength of the castings may, with the consent of the purchaser's inspector, be welded by an approved process. The defects shall first be cleaned out to solid metal, and after the castings are welded they shall be heat treated, if required by the purchaser's inspector.

2.5.4c—Castings shall not be painted unless so specified.

2.6—Inspection and Rejection

2.6.1—Inspection:

2.6.1a—The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is

being furnished in accordance with these specifications. All tests (except check analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

2.6.1b—The purchaser may, at his own expense, in his own laboratory or elsewhere, make tests to govern the acceptance or rejection of material ordered.

2.6.2—Rejection:

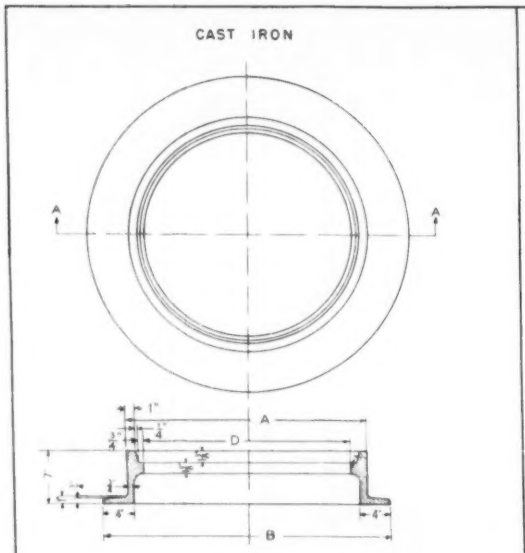
2.6.2a—Material represented by samples which fail to conform to the requirements of these specifications will be rejected. Any rejection based on tests made in accordance with these specifications shall be reported to the manufacturer within five working days from the receipt of samples by the purchaser.

2.6.2b—Material which shows injurious defects following original inspection and acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

2.6.3—Rehearing:

Tested samples representing rejected material shall be held for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

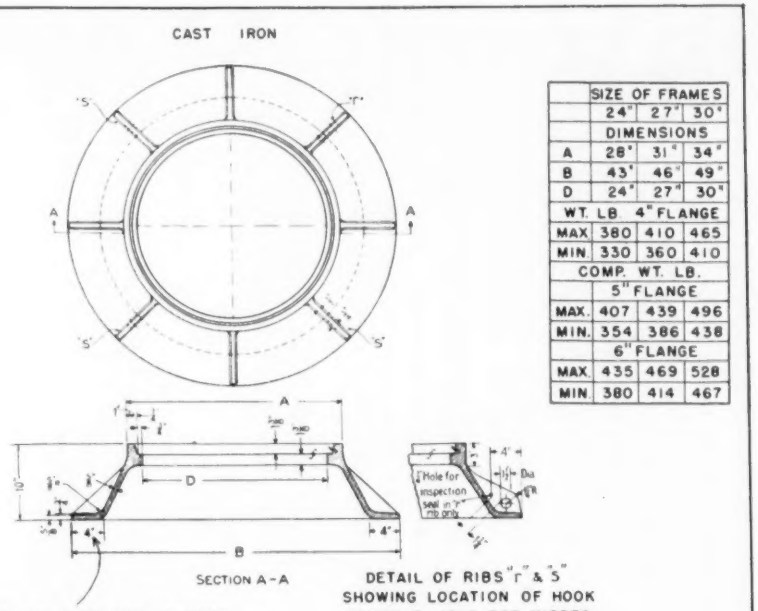
(*Figs. 3 through 22 on following pages*)



FRAMES MAY ALSO HAVE FLANGE WIDTHS OF 5" OR 6" AS ORDERED

	SIZE OF FRAMES		
	22"	27"	30"
	DIMENSIONS		
D	22"	27"	30"
A	26"	31"	34"
B	32½"	37⅛"	40½"
	COMP. WT. LB.		
MAX.	250	300	325
MIN.	225	270	295

FIG. 3



	SIZE OF FRAMES		
	24"	27"	30"
	DIMENSIONS		
A	28"	31"	34"
B	43"	46"	49"
D	24"	27"	30"
	WT. LB. 4" FLANGE		
MAX.	380	410	465
MIN.	330	360	410
	COMP. WT. LB.		
	5" FLANGE		
MAX.	407	439	496
MIN.	354	386	438
	6" FLANGE		
MAX.	435	469	528
MIN.	380	414	467

FRAMES MAY ALSO HAVE FLANGE WIDTHS OF 5" OR 6" AS ORDERED. WHEN THE FRAMES ARE MADE WITH FLANGE WIDTHS OF 5" OR 6" THE SHAPE AND DIMENSIONS OF THE RIBS ARE TO BE THE SAME AS SHOWN ABOVE

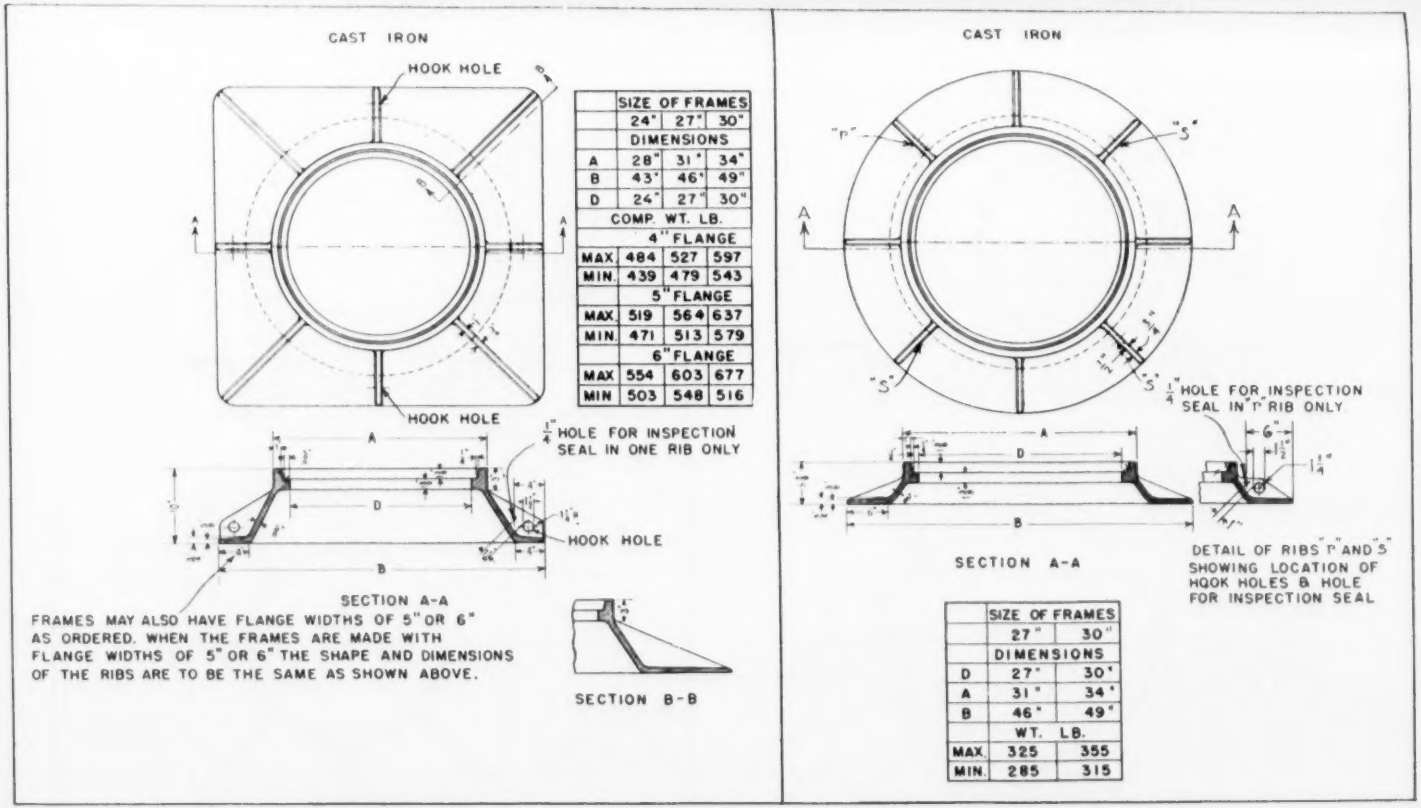
DETAIL OF RIBS "T" & "S" SHOWING LOCATION OF HOOK HOLES & HOLE FOR INSPECTION SEAL

FIG. 4

FIG. 3. Manhole Frames—Straight Type, Round Base, 22-, 27- and 30-in. Openings

FIG. 4. Manhole Frames—Flared Type, Round Base, 24-, 27- and 30-in. Openings

FIG. 4. Manhole Frames—Flared Type, Round Base, 24-, 27- and 30-in. Openings


CAST IRON
HOOK HOLE
HOOK HOLE
A
A
D
B
1/4" HOLE FOR INSPECTION SEAL IN ONE RIB ONLY
HOOK HOLE
SECTION A-A
FRAMES MAY ALSO HAVE FLANGE WIDTHS OF 5" OR 6" AS ORDERED. WHEN THE FRAMES ARE MADE WITH FLANGE WIDTHS OF 5" OR 6" THE SHAPE AND DIMENSIONS OF THE RIBS ARE TO BE THE SAME AS SHOWN ABOVE.
SECTION B-B
CAST IRON
"P"
"S"
"S"
"S"
1/4" HOLE FOR INSPECTION SEAL IN "P" RIB ONLY
SECTION A-A
DETAIL OF RIBS "P" AND "S" SHOWING LOCATION OF HOOK HOLES & HOLE FOR INSPECTION SEAL

	SIZE OF FRAMES		
	24"	27"	30"
	DIMENSIONS		
A	28"	31"	34"
B	43"	46"	49"
D	24"	27"	30"
	COMP. WT. LB.		
	4" FLANGE		
MAX.	484	527	597
MIN.	439	479	543
	5" FLANGE		
MAX.	519	564	637
MIN.	471	513	579
	6" FLANGE		
MAX.	554	603	677
MIN.	503	548	516

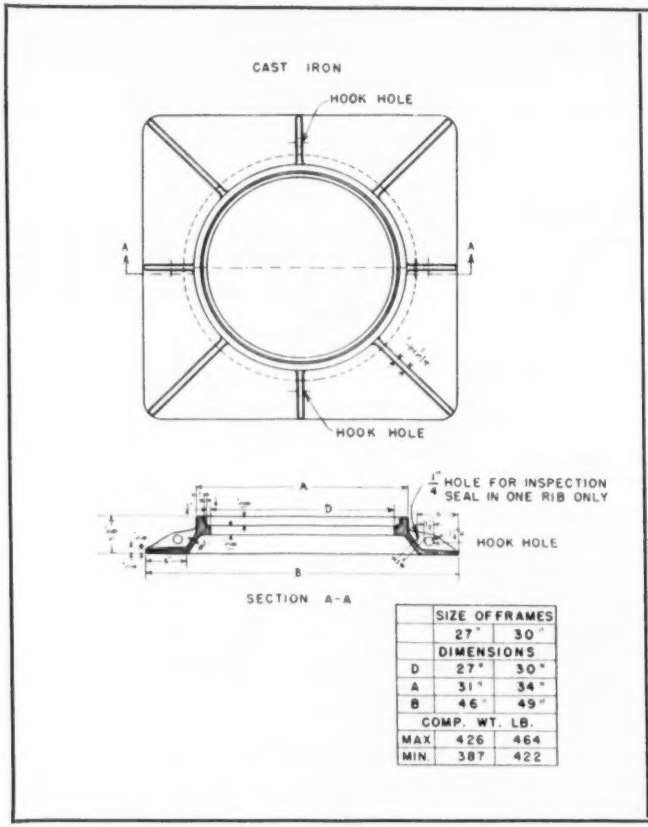
	SIZE OF FRAMES	
	27"	30"
	DIMENSIONS	
D	27"	30"
A	31"	34"
B	46"	49"
	WT. LB.	
MAX.	325	355
MIN.	285	315

FIG. 5

FIG. 6

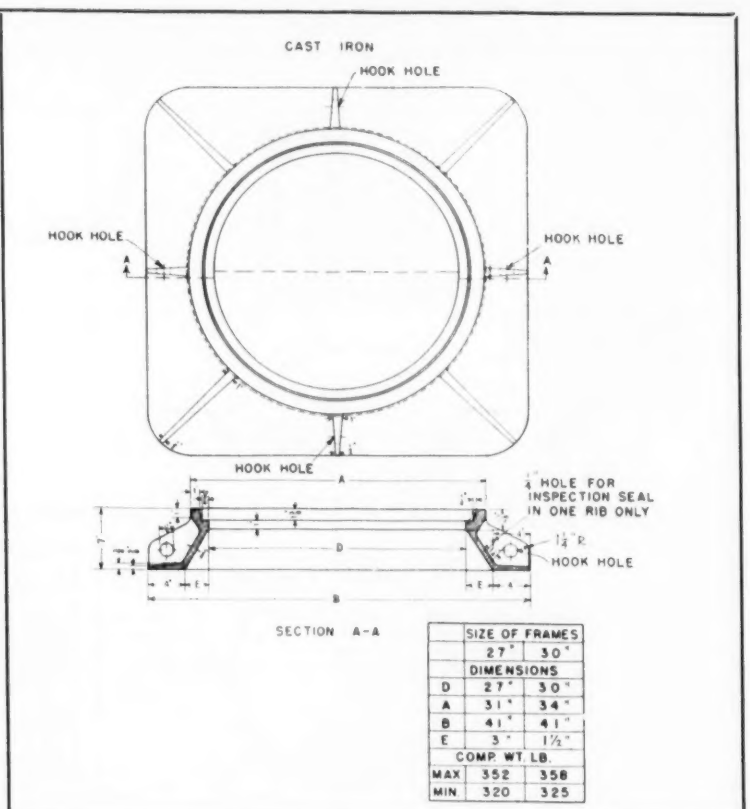
FIG. 5. Manhole Frames—Flared Type, Square Base, 24-, 27- and 30-in. Openings, 10-in. Height

FIG. 6. Manhole Frames—Shallow Flared Type, Round Base, 27- and 30-in. Openings



	SIZE OF FRAMES	
	27"	30"
	DIMENSIONS	
D	27"	30"
A	31"	34"
B	46"	49"
	COMP. WT. LB.	
MAX	426	464
MIN	387	422

FIG. 7



	SIZE OF FRAMES	
	27"	30"
	DIMENSIONS	
D	27"	30"
A	31"	34"
B	41"	41"
E	3"	1½"
	COMP. WT. LB.	
MAX	352	358
MIN	320	325

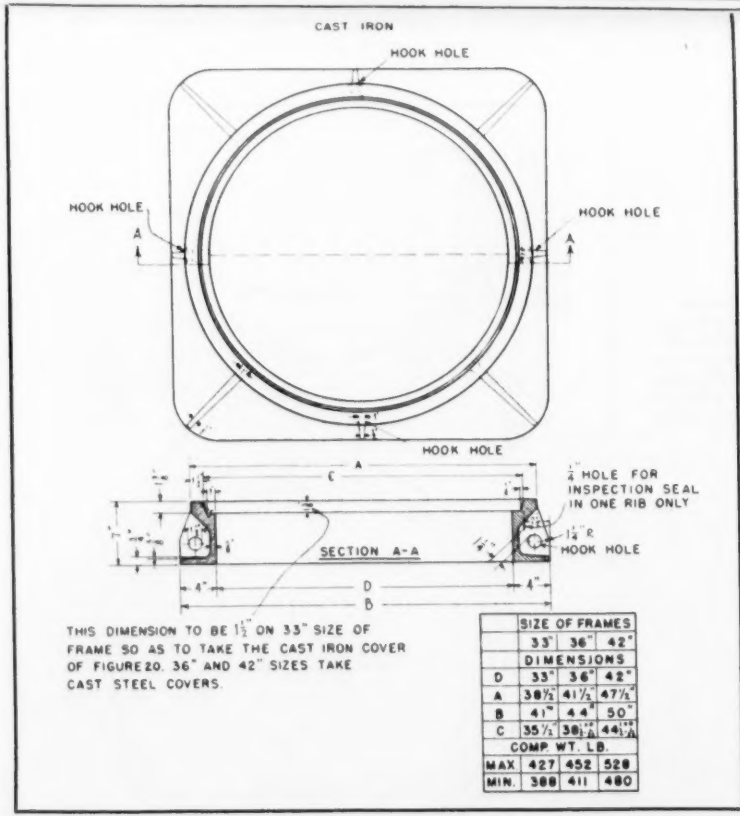
FIG. 8

FIG. 7. Manhole Frames—Shallow Flared Type, Square Base, 27- and 30-in. Openings

FIG. 8. Manhole Frames—Flared Type, Square Base, 27- and 30-in. Openings, 7-in. Height

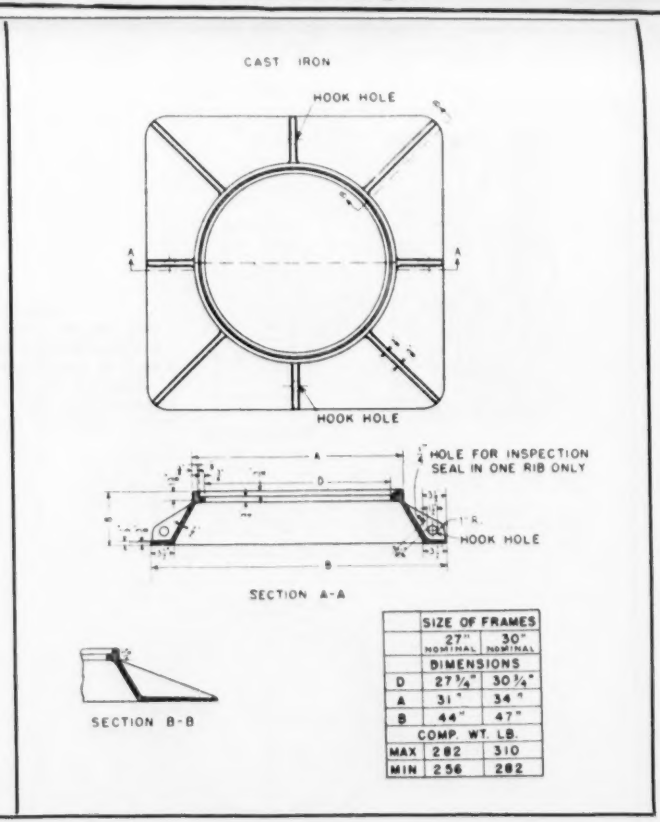
Fig. 8. Manhole Frames—Shallow Flared Type, Square Base, 27- and 30-in. Openings

Fig. 8. Manhole Frames—Flared Type, Square Base, 27- and 30-in. Openings, 7-in. Height



	SIZE OF FRAMES		
	33"	36"	42"
	DIMENSIONS		
D	33"	36"	42"
A	30½"	41½"	47½"
B	41"	44"	50"
C	35½"	38½"	44½"
	COMP. WT. LB.		
MAX	427	452	528
MIN.	388	411	480

Fig. 9

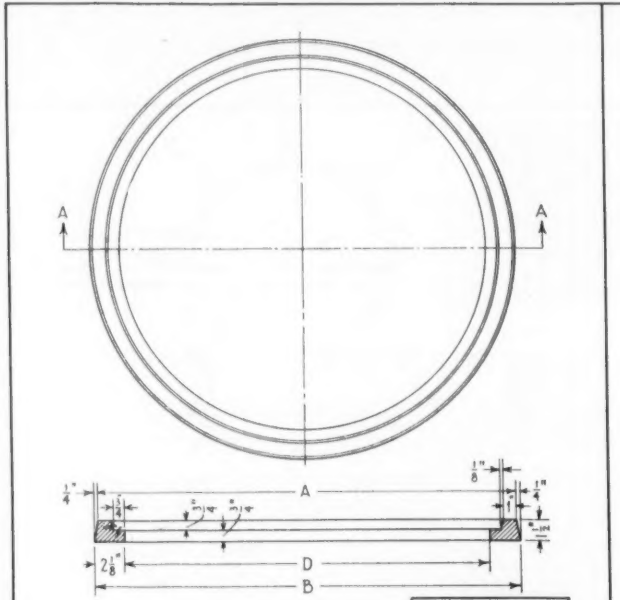


	SIZE OF FRAMES	
	27" NOMINAL	30" NOMINAL
	DIMENSIONS	
D	27¾"	30¾"
A	31"	34"
B	44"	47"
	COMP. WT. LB.	
MAX	282	310
MIN	256	282

Fig. 10

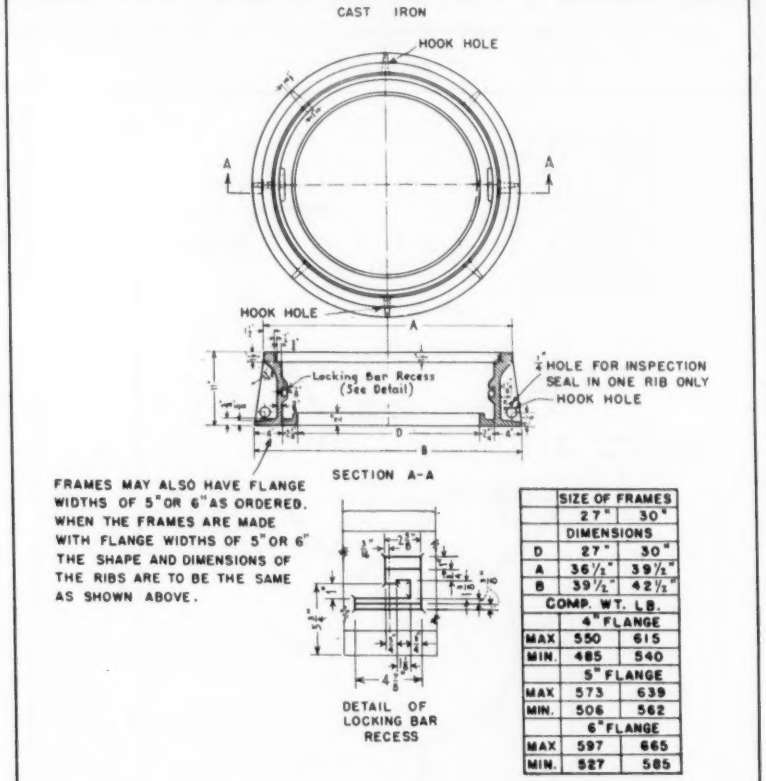
Fig. 9. Manhole Frames—Flared Type, Square Base, 33-, 36- and 42-in. Openings, Light Weight

Fig. 10. Manhole Frames—Flared Type, Square Base, Light Weight, Not Intended for Vehicular Traffic, 27- and 30-in. Openings



	SIZE OF FRAMES	
	27" NOMINAL	30" NOMINAL
	DIMENSIONS	
D	27 1/4"	30 1/4"
A	31 1/2"	34 1/2"
B	32"	35"
	COMP. WT. LB.	
MAX.	65	70
MIN.	59	64

FIG. 11


CAST IRON
HOOK HOLE
A
A
HOOK HOLE
A
Locking Bar Recess
(See Detail)
1/4" HOLE FOR INSPECTION SEAL IN ONE RIB ONLY
HOOK HOLE
D
B
SECTION A-A
FRAMES MAY ALSO HAVE FLANGE WIDTHS OF 5" OR 6" AS ORDERED. WHEN THE FRAMES ARE MADE WITH FLANGE WIDTHS OF 5" OR 6" THE SHAPE AND DIMENSIONS OF THE RIBS ARE TO BE THE SAME AS SHOWN ABOVE.
DETAIL OF LOCKING BAR RECESS

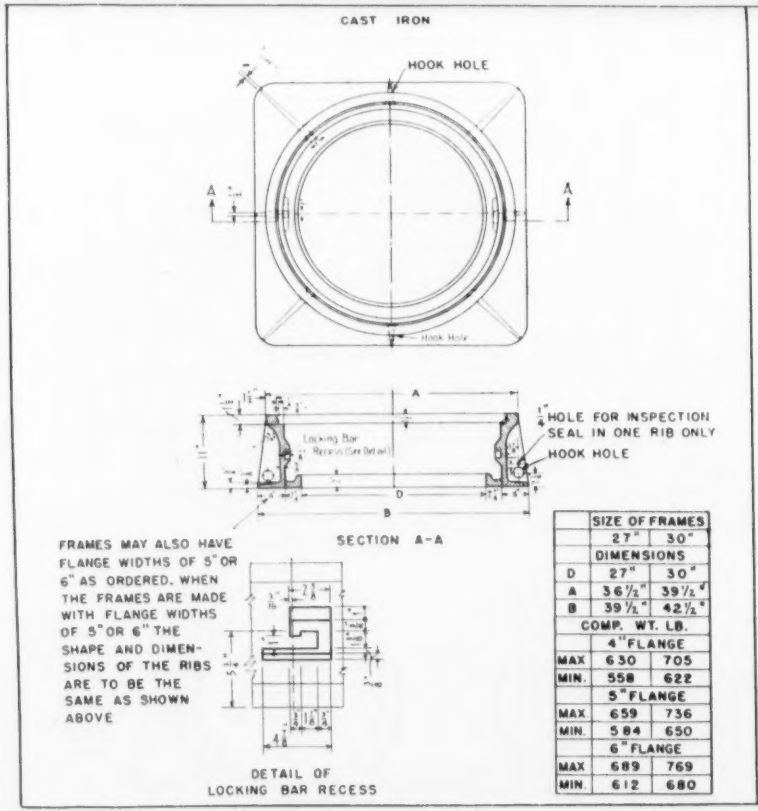
	SIZE OF FRAMES	
	27"	30"
	DIMENSIONS	
D	27"	30"
A	36 1/2"	39 1/2"
B	39 1/2"	42 1/2"
	COMP. WT. LB.	
	4" FLANGE	
MAX	550	615
MIN.	485	540
	5" FLANGE	
MAX	573	639
MIN.	506	562
	6" FLANGE	
MAX	597	665
MIN.	527	585

FIG. 12

FIG. 11. Manhole Frames—Ring Type, Not Intended for Vehicular Traffic, 27- and 30-in. Openings

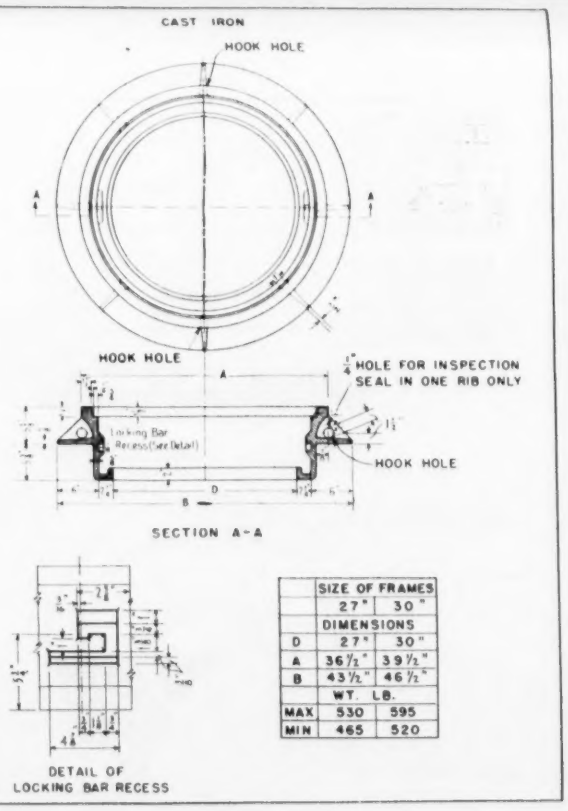
FIG. 12. Manhole Frames—Straight Type, Round Base, for Inner Cover and Locking Bar, 27- and 30-in. Openings

FIG. 12. Manhole Frames—Straight Type, Round Base, for Inner Cover and Locking Bar, 27- and 30-in. Openings


CAST IRON
HOOK HOLE
A
A
Hook Hole
A
Locking Bar Recess (See Detail)
1/4" HOLE FOR INSPECTION SEAL IN ONE RIB ONLY
HOOK HOLE
D
B
SECTION A-A
FRAMES MAY ALSO HAVE FLANGE WIDTHS OF 5" OR 6" AS ORDERED. WHEN THE FRAMES ARE MADE WITH FLANGE WIDTHS OF 5" OR 6" THE SHAPE AND DIMENSIONS OF THE RIBS ARE TO BE THE SAME AS SHOWN ABOVE
DETAIL OF LOCKING BAR RECESS

	SIZE OF FRAMES	
	27"	30"
	DIMENSIONS	
D	27"	30"
A	36½"	39½"
B	39½"	42½"
	COMP. WT. LB.	
	4" FLANGE	
MAX.	630	705
MIN.	558	622
	5" FLANGE	
MAX.	659	736
MIN.	584	650
	6" FLANGE	
MAX.	689	769
MIN.	612	680

FIG. 13

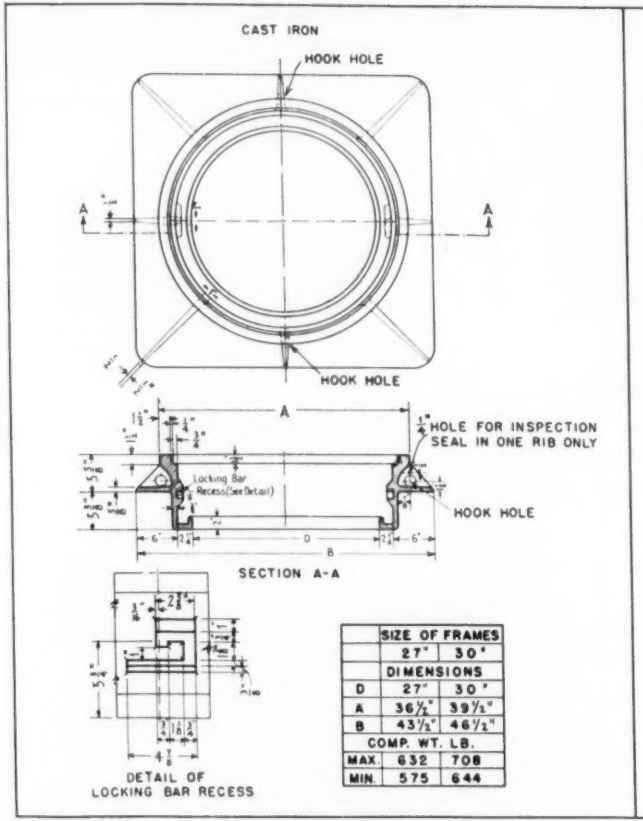


	SIZE OF FRAMES	
	27"	30"
	DIMENSIONS	
D	27"	30"
A	36½"	39½"
B	43½"	46½"
	WT. LB.	
MAX	530	595
MIN	465	520

FIG. 14

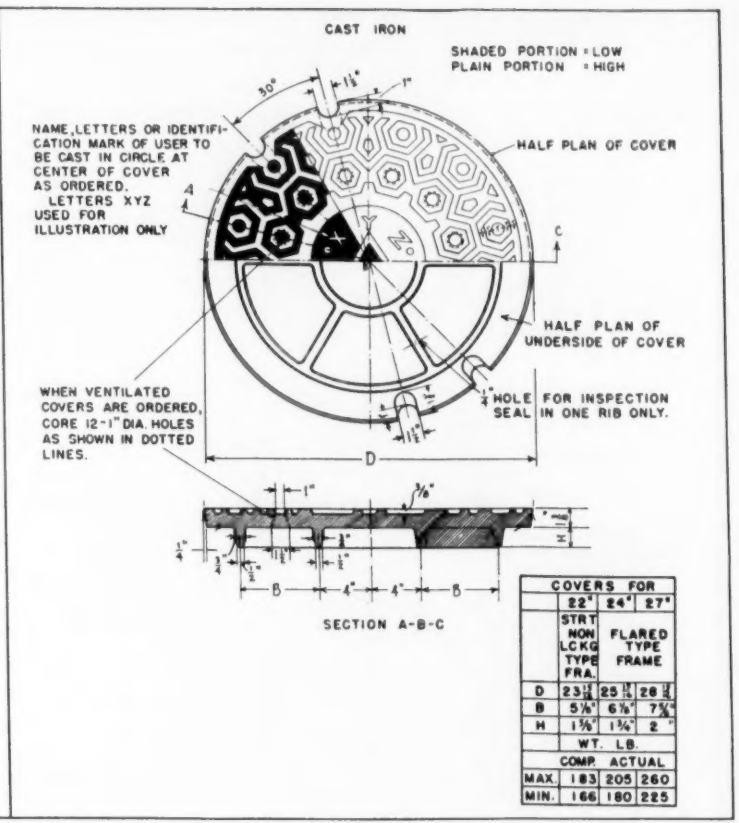
FIG. 13. Manhole Frames—Straight Type, Square Base, for Inner Cover and Locking Bar, 27- and 30-in. Openings

FIG. 14. Manhole Frames—Shallow Straight Type, Round Base, for Inner Cover and Locking Bar, 27- and 30-in. Openings



	SIZE OF FRAMES	
	27"	30"
	DIMENSIONS	
D	27"	30"
A	36½"	39½"
B	43½"	46½"
	COMP. WT. LB.	
MAX.	632	708
MIN.	575	644

FIG. 15



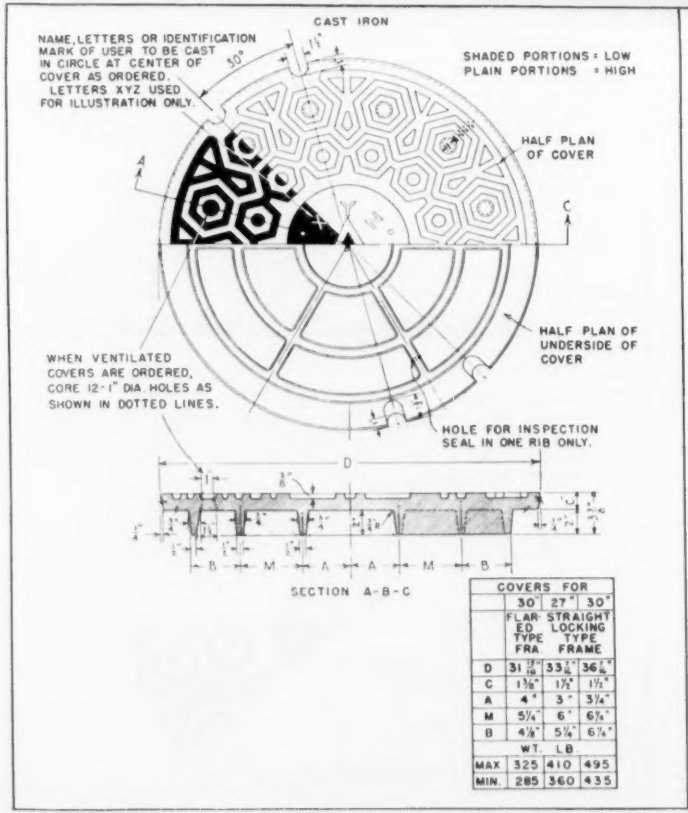
	COVERS FOR		
	22"	24"	27"
	STRT NON LCKG TYPE FRA.	FLARED TYPE FRAME	
D	23 11/16"	25 11/16"	28 11/16"
B	5⅛"	6⅛"	7⅝"
H	1⅞"	1¾"	2"
	WT. LB.		
	COMP.	ACTUAL	
MAX.	183	205	260
MIN.	166	180	225

FIG. 16

FIG. 15. Manhole Frames—Shallow Straight Type, Square Base, for Inner Cover and Locking Bar, 27- and 30-in. Openings

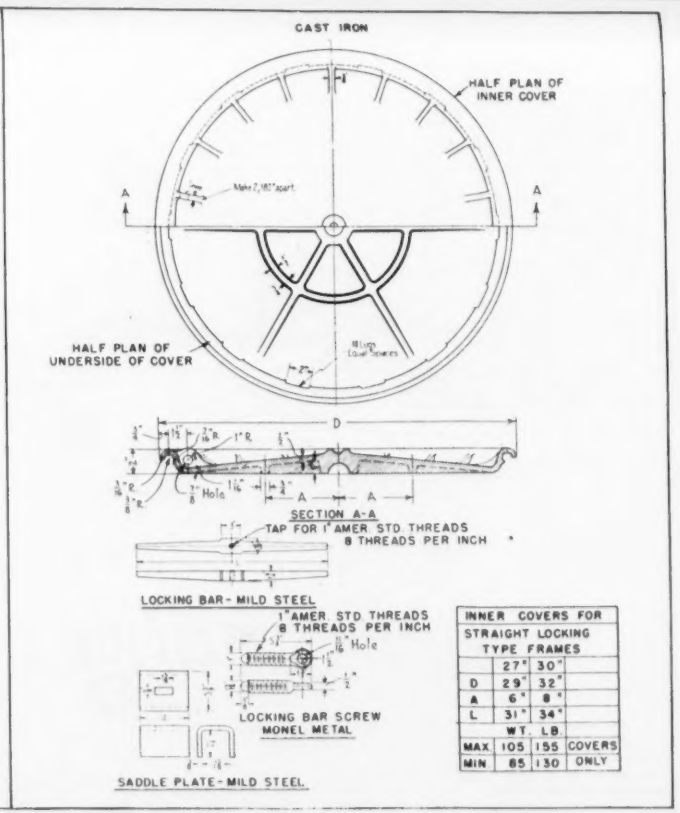
FIG. 16. Manhole Covers

FIG. 16. Manhole Covers


CAST IRON
NAME, LETTERS OR IDENTIFICATION MARK OF USER TO BE CAST IN CIRCLE AT CENTER OF COVER AS ORDERED. LETTERS XYZ USED FOR ILLUSTRATION ONLY.
SHADED PORTIONS = LOW
PLAIN PORTIONS = HIGH
HALF PLAN OF COVER
HALF PLAN OF UNDERSIDE OF COVER
WHEN VENTILATED COVERS ARE ORDERED, CORE 12-1" DIA. HOLES AS SHOWN IN DOTTED LINES.
HOLE FOR INSPECTION SEAL IN ONE RIB ONLY.
SECTION A-B-C

	COVERS FOR		
	30" FLARED TYPE FRAME	27" STRAIGHT LOCKING TYPE FRAME	30" STRAIGHT LOCKING TYPE FRAME
D	31 $\frac{13}{16}$"	33 $\frac{1}{4}$"	36 $\frac{1}{4}$"
C	1 $\frac{3}{16}$"	1 $\frac{7}{8}$"	1 $\frac{7}{8}$"
A	4"	3"	3 $\frac{1}{4}$"
M	5 $\frac{1}{4}$"	6"	6 $\frac{7}{8}$"
B	4 $\frac{1}{8}$"	5 $\frac{1}{4}$"	6 $\frac{7}{8}$"
	WT. LB		
MAX	325	410	495
MIN.	285	360	435

FIG. 17

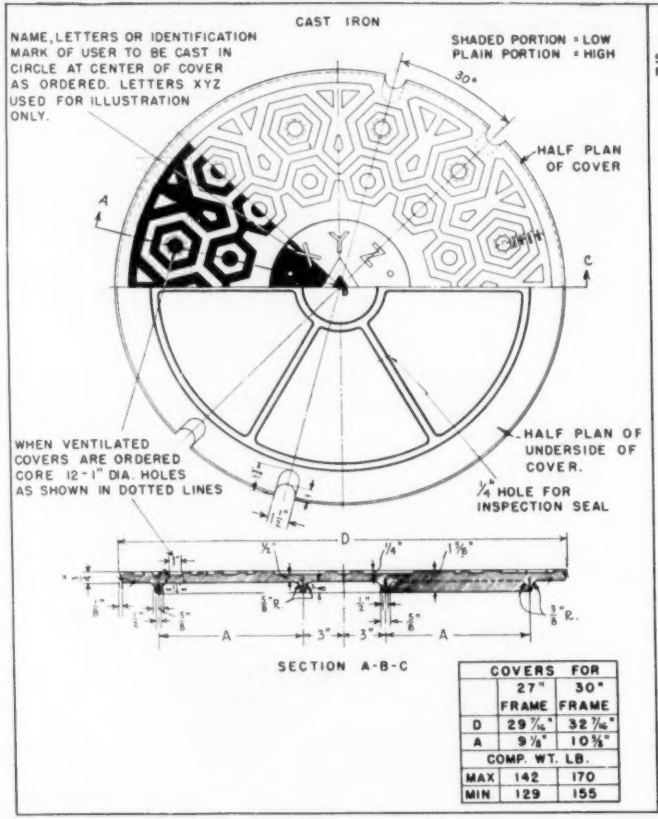

CAST IRON
HALF PLAN OF INNER COVER
HALF PLAN OF UNDERSIDE OF COVER
SECTION A-A
TAP FOR 1" AMER STD THREADS
8 THREADS PER INCH
LOCKING BAR - MILD STEEL
1" AMER STD THREADS
8 THREADS PER INCH
LOCKING BAR SCREW
MONEL METAL
SADDLE PLATE - MILD STEEL

INNER COVERS FOR STRAIGHT LOCKING TYPE FRAMES			
	27"	30"	
D	29"	32"	
A	6"	8"	
L	31"	34"	
	WT. LB		
MAX	105	155	COVERS
MIN	85	130	ONLY

FIG. 18

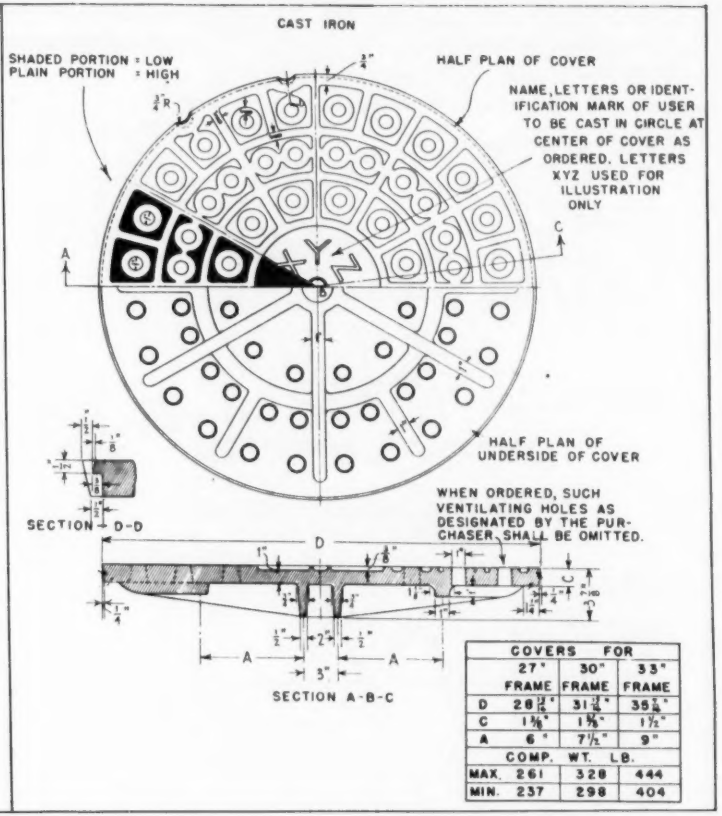
FIG. 17. Manhole Covers

FIG. 18. Inner Cover and Associated Parts


CAST IRON
NAME, LETTERS OR IDENTIFICATION MARK OF USER TO BE CAST IN CIRCLE AT CENTER OF COVER AS ORDERED. LETTERS XYZ USED FOR ILLUSTRATION ONLY.
SHADED PORTION = LOW
PLAIN PORTION = HIGH
30°
HALF PLAN OF COVER
A
C
WHEN VENTILATED COVERS ARE ORDERED CORE 12-1" DIA. HOLES AS SHOWN IN DOTTED LINES
HALF PLAN OF UNDERSIDE OF COVER.
¼" HOLE FOR INSPECTION SEAL
SECTION A-B-C

	COVERS FOR 27" FRAME	30" FRAME
D	29 7/16"	32 7/16"
A	9 1/8"	10 1/8"
COMP. WT. LB.		
MAX	142	170
MIN	129	155

FIG. 19


CAST IRON
SHADED PORTION = LOW
PLAIN PORTION = HIGH
HALF PLAN OF COVER
NAME, LETTERS OR IDENTIFICATION MARK OF USER TO BE CAST IN CIRCLE AT CENTER OF COVER AS ORDERED. LETTERS XYZ USED FOR ILLUSTRATION ONLY
A
C
HALF PLAN OF UNDERSIDE OF COVER
WHEN ORDERED, SUCH VENTILATING HOLES AS DESIGNATED BY THE PURCHASER SHALL BE OMITTED.
SECTION D-D
SECTION A-B-C

	COVERS FOR 27" FRAME	30" FRAME	33" FRAME
D	28 12/16"	31 12/16"	35 3/16"
C	1 5/16"	1 5/16"	1 1/2"
A	6"	7 1/2"	9"
COMP. WT. LB.			
MAX.	261	328	444
MIN.	237	298	404

FIG. 20

FIG. 19. Manhole Covers—Not Intended for Vehicular Traffic

FIG. 20. Manhole Cover

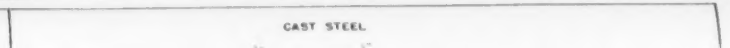


FIG. 20. Manhole Cover

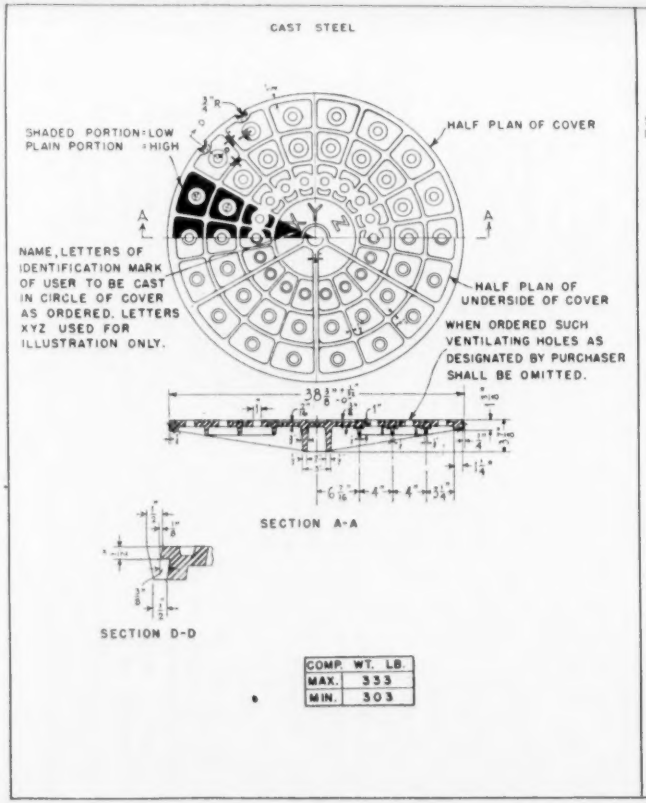

CAST STEEL
SHADED PORTION=LOW
PLAIN PORTION =HIGH
HALF PLAN OF COVER
NAME, LETTERS OF IDENTIFICATION MARK OF USER TO BE CAST IN CIRCLE OF COVER AS ORDERED. LETTERS XYZ USED FOR ILLUSTRATION ONLY.
HALF PLAN OF UNDERSIDE OF COVER
WHEN ORDERED SUCH VENTILATING HOLES AS DESIGNATED BY PURCHASER SHALL BE OMITTED.
SECTION A-A
SECTION D-D
COMP. WT. LB.
MAX. 333
MIN. 303

FIG. 21

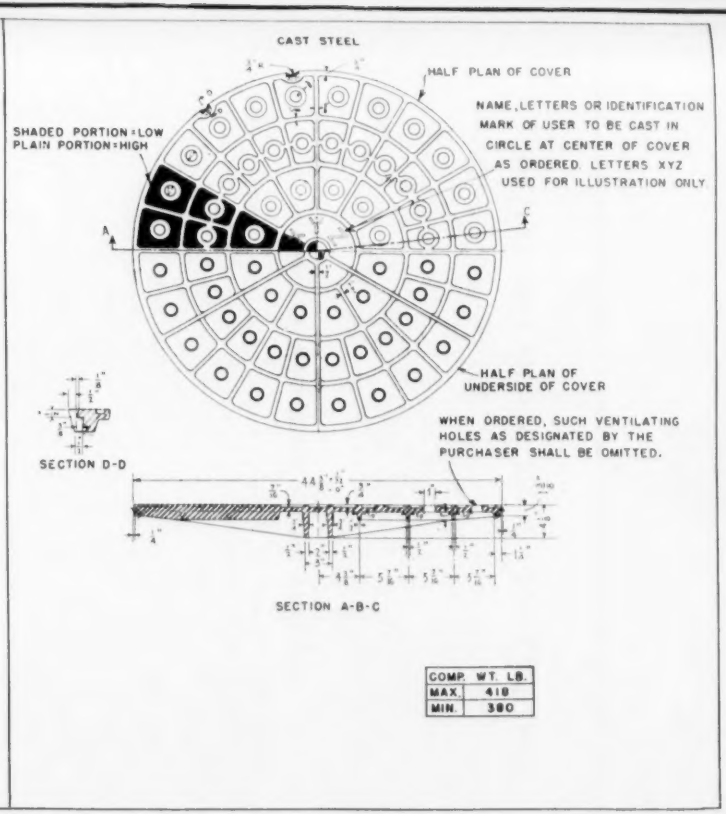

CAST STEEL
HALF PLAN OF COVER
NAME, LETTERS OR IDENTIFICATION MARK OF USER TO BE CAST IN CIRCLE AT CENTER OF COVER AS ORDERED. LETTERS XYZ USED FOR ILLUSTRATION ONLY
SHADED PORTION=LOW
PLAIN PORTION=HIGH
HALF PLAN OF UNDERSIDE OF COVER
WHEN ORDERED, SUCH VENTILATING HOLES AS DESIGNATED BY THE PURCHASER SHALL BE OMITTED.
SECTION D-D
SECTION A-B-C
COMP. WT. LB.
MAX. 418
MIN. 380

FIG. 22

FIG. 21. Manhole Cover—for 36-in. Frame

FIG. 22. Manhole Cover—for 42-in. Frame

ABSTRACTS OF WATER WORKS LITERATURE

Key, 31: 481(Mar. '39) indicates volume 31, page 481, issue dated March 1939. If the publication is paged by issues, **31:** 3: 481, (Mar. '39) indicates volume 31, number 3, page 481. Initials following an abstract indicate reproduction, by permission, from periodicals as follows: *B.H.—Bulletin of Hygiene (British); C.A.—Chemical Abstracts; P.H.E.A.—Public Health Engineering Abstracts; W.P.R.—Water Pollution Research (British); I.M.—Institute of Metals (British).*

WARTIME WATER WORKS PROBLEMS

Water Supply First Target of Saboteurs: Symposium Presents Methods of of Guarding Plants. SAMRAY SMITH. Popular Govt. **8:** 3: 9 (Mar. '42). North Carolina symposium on protection of water supplies attended by 450, problems of sabotage, bomb damage, chem. and bact. poisoning and mutual aid plans discussed. British experience indicates little bombing damage done to pumping stations and filter plants; with good air defense only 1 main in 100 mi. put out of commission. May be 100 times as bad with poor air defense. Probability of damage to vital structures or public services from random bombing of avg. city rather less than may be expected. Radius of destruction of 100 lb. bomb due to: (1) earth shock is 25′; (2) air blast, 70′; 500 lb. bomb: (1) is 45′ and (2) 200′; 2000 lb. bomb: (1) 70′ and (2) 400′. In Britain water mains and sewers broken from 60′ to 120′ laterally from crater and partially destroyed at greater distances. Sabotage, aside from outright destruction, consists in slowing down production by reduced lighting, stink bombs, fake bombs, fire scares, and lowering morale by spreading rumors. Utilities should guard against arson, bombs and explosives, and mechanical sabotage, such as water in lubricating and fuel oil, acids in lubricants and on stay and guy wires, acids and alkalies in boilers, syrup in oil, emery dust in machinery, destruction of rubber by any kind of oil. Sabotage best prevented by systematic program of prevention. Chem. poisoning of water supply possibility, but remote probability. All that can be done is to watch anals. carefully and protect water supply physically as far as possible, having doctors keep careful lookout for first signs of chem. poisoning. Same measures apply to bact. poisoning. Addn. of Cl alone will not carry sufficient residual throughout system to safeguard against typhoid, ordinary dysentery and cholera. Chloramination recommended. Ordinary chlorine concns. sufficient unless adjacent water lines and sewers broken by bombs. Importance of water system stressed; recommended that officials co-operate with police in guarding. Plan for emergency supplies, increase no. of samples to be tested, have positive means of identification for water works operators. Mutual aid plan of N.C. discussed—*Martin E. Flentje.*

Water Valve Operation Under Emergency Conditions. A. S. G. MUSGRAVE. Eng. News-Rec. **128:** 764 (May 7, '42). In Oak Bay, B.C., community of 10,000 people, nearly 400 valves in water system. Ordinarily only 2 men completely familiar with location and operation of these valves. Valve covers have been cleaned and painted bright yellow and maps prepared dividing system into 16 areas. Two intelligent

residents chosen from each area and specially trained as water wardens and supplied with maps of their districts, clearly showing each valve and distance of main from property lines. Each valve given distinguishing no. and lists compiled showing nos. of valves which have to be closed to isolate individual blocks. Water wardens enrolled under Engineering A.R.P. Services. Their sole duty to be familiar with location and operation of valves. They were instructed by the regular employees.—*R. E. Thompson.*

Water Demands and Sewage Production in Military Cantonments. SAMUEL M. ELLSWORTH. Am. J. Pub. Health. **32:** 21 (Jan. '42). Reliable water consumption data for military cantonments not as readily obtainable as for munic. installations. Design of both sewage and water works at Camp Edwards based on 100 gpd. per capita and max. rate of twice this amt. Water consumption from Apr. to July inclusive summarized (rate of consumption given in gpd. per capita): (1) avg., excluding Sat., Sun. and holidays, 94; (2) avg. of max. daily consumption each week, 104.3; (3) avg. daily consumption during max. 7-day week, 92.3; (4) same as (3) excluding Sat. and Sun., 97.0. Water consumption reaches peak rate at about 7 A.M., decreases to approx. ½ peak rate at 11 A.M., rises to another peak following noonday meal, falling off again in early P.M. Increase begins again at about 3 P.M. to high point at 4, falls off until 9 and increases again to 10 P.M., with rate receding from then on until min. reached at 3 A.M. Avg. sewage flow from regimental area was 90.5 gpd. per capita; max. flow at about 7:20 A.M. found to be 196 and min. flow, occurring between 3 and 4 A.M., 51 gpd. per capita. Water consumption may be appreciably increased if "Aqua" system of gasoline displacement used; this system at 2 moderate-sized military air fields requires water at rate of approx. 350,000 gal. in 4 hr. (2.1 mgd.)—*Martin E. Flentje.*

Water and Sewerage Design Problems in a Boomtown Area. C. M. STANLEY. Eng. News-Rec. **128:** 548 (Apr. 9, '42). Owing to constr. of large war plant in area, pop. of Danville, Iowa, increased suddenly from 309 to 1,200 and that of Middletown from 134 to 400. Neither town had public water or sewage facilities, and prompt action was necessary. Appeals for financial assistance made to Defense Public Works div. of Federal Works Agency and, as result, Danville will contribute $25,000 of estd. total cost of $120,000 and town will construct, own and operate water and sewage systems. In case of Middletown, Defense Public Works div. will finance entire cost of $47,500 and will own and operate facilities for duration of emergency. Both water supplies will be derived from wells, that in Danville being carried down to St. Peter sandstone at depth of about 1,200′ and that in Middletown to depth of 185′ in old river channel. Motor-driven turbine-type pumps will deliver water to concrete storage reservoirs of 60,000 and 30,000 gal. capac. at ground surface, no steel plate being available for elevated tanks. Motor-driven booster pumps will maint. pressure in distr. systems, which will consist of c-i. or asbestos-cement pipe and lead services. Efforts made to minimize use of structural steel, c-i. pipe, copper, bronze, brass and aluminum. Studies indicated that annual pumping costs at Danville will be only about $100 more than with conventional elevated tank floating on system. Danville sewage plant will discharge into drainage area of impounding reservoir used for emergency water supply for war plant and works have therefore been designed to produce effluent of degree of purity seldom equaled in plants of such capac.—*R. E. Thompson.*

Health Agencies—Their Responsibilities and Their Opportunities During the Present Crisis. PAUL V. MCNUTT. U.S. Pub. Health Rpts. **57:** 685 (May 8, '42). Now engaged in "shooting war." Its vigorous prosecution must take precedence over everything else. Health depts. will give up personnel but discharge responsibilities with such organization as retained or recruited. Many newly imposed duties will be fulfilled with improvised forces only by prodigious effort and possible curtailment of certain activities dispensable to conducting war.

Industrial hygiene problem must be attacked immediately and vigorously. Sickness and disability which steals workers' time or saps energy threatens natl. security, gives aid and comfort to enemy. In view of present crucial needs, insufficient effort put forth as yet. States must make considerably greater financial outlays. Greater wisdom, initiative and sustained effort required. Although health agencies given broader legislative and statutory authority than almost any other govt. branch, and rights upheld by judicial decisions, many continue operating by tradition. Meantime community may sorely need kind of addnl. help health dept. peculiarly equipped to give. Faulty industrial hygiene may be robbing workers and country of needed goods. San. codes may be hopelessly outmoded. Better housing may be urgent health need. Organized vice may be impeding military effort. Must realize business as usual is out. Inertia and solicitude for special interests cannot be tolerated in health agencies today. In event of bombing homes, factories and offices, has state health dept. well-defined plan for manning first aid stations; organizing ambulances and hospital services; paying hospital bills; providing blood bank with sufficient plasma; emergency treatment of water? If these questions remain unanswered, confusion recrimination, awful sense of responsibility for needlessly lost lives may result. Teamwork and co-operation today nothing less than matters of natl. salvation. Office of Defense Health and Welfare Services established as co-ordinating agency. As to opportunities, many worth-while and long overdue enterprises undertaken. Many communities for first time experiencing full-time pub. health organization. Groundwork laid for states to carry on permanently. Community facilities program providing hospitals, health centers, san. installations without which health depts. previously handicapped seriously. Consider opportunity for health education presented by 8,000 civilian defense organizations with 5,000,000 volunteer members.—*Ralph E. Noble.*

State and Territorial Health Officers Confer on Wartime Tasks. ANON. U.S. Pub. Health Rpts. **57:** 696 (May 8, '42). Bills introduced since last conference but not yet enacted include: H.R. 1791, establishing new executive dept. known as Dept. of Health; H.R. 1110, 3778, 4106, 5676; S. 1121 and S. 1913; all establishing Div. of Water Pollution Control in U.S. Pub. Health Service. Following appropriation bills enacted: Pub. Law 9, approved Mar. 1, '41, $525,000 for emergency health and sanitation activities related to defense. Pub. Law 146, approved July 1, '41, $35,480,700 for U.S. Pub. Health Service during fiscal yr. '42. Of this amt., $1,235,000 for emergency health and sanitation activities related to defense. Pub. Law 150, approved July 3, '41, $1,940,000 for emergency health and sanitation activities pertaining to defense. Pub. Law 463, approved Feb. 21, '42, $77,481 for disease and sanitation investigations; $1,295,000 for emergency health and sanitation defense activities. *Public Health Service Reserve.* To have trained personnel available for wartime emergency duty, U.S.P.H.S. granting inactive reserve commissions to qualified pub. health personnel (physicians, engrs., dentists) who will be called to temporary active duty when and where needed upon request by state health officer to Surgeon General. Salary and travel paid by U.S.P.H.S. State health officers requested by Surgeon General to recommend personnel for such reserve commissions. Expect approx. 2,000 needed. Rank granted dependent upon age, qualifications and ratio of reserve officer to regulars. Pay and allowances equal to those of Army med. officers. Ordinary physical requirements waived, criterion being ability to do task required. No definite upper age limit set.—*Ralph E. Noble.*

Sanitation Activities in the Southeastern States in Connection With National Defense. E. C. SULLIVAN AND J. S. WILEY. U.S. Pub. Health Repts. **27:** 616 (Apr. 24, '42). *Present Natl. Emergency.* Health protection important item in natl. defense activities. One of

health officer's prin. duties now to conserve health of military and naval forces. Latter authorities responsible for same in their limited jurisdiction areas. Part of soldier's time, however, spent off post in adjacent civil communities and other areas, on training or leave. Even if this time brief, could be significant, as some infections acquired quickly. Rests with pub. health officials, therefore, to protect health of fighting personnel "off duty" and on. Also essential that health of workers in defense industries safeguarded to insure rapid materials production. Must protect and control health of public at large for good of people and maint. of natl. morale at high level. *Extra-Cantonment Activities.* At request of Secy. of War, 9 sr. U.S.P.H.S. med. officers assigned as liaison officers to 9 Army Corps area headquarters to facilitate relations between civilian and military health authorities. Main duty to keep former informed as to public health needs of military forces, and latter apprised of health and san. conditions in areas to be used; also stimulate further development and full utilization of existing facilities in areas where armed forces or natl. defense employees concentrated. *Mosquito Control.* U.S.P.H.S. initiated oiling program in southern extra-cantonment areas, May–June '41. Taken over by WPA July 1, '41. In S.C., Ga., Fla., Ala., Miss. and La., mosquito control drainage projects submitted, 34; certified as defense-connected, 12; operating, 8; completed, 1. Larvicidal projects operating or operated, statewide certified, 46. *Reconnaissance Surveys of Defense Areas.* Made by U.S.P.H.S. team of engr. and med. officer in munic. and rural areas within 25 mi. of each major completed or projected cantonment, to anticipate needs before existing facilities overtaxed. 42 surveys completed. Provided essential information about community facility needs of water supply, sewers and hospitals to many govt. defense agencies. *Community Facilities Law.* Provided $150,000,000 for constr. of water plants and systems, sewer systems and treatment plants, health centers, comfort stations, venereal disease clinics, hospitals and incinerators, after shown acute need in defense situation rather than long standing community need, proper recommendation and approval by President. *Milk Sanitation Control.* In '41, U.S.P.H.S. milk san. personnel surveyed milksheds and pasteurization plants in extra-cantonment areas. Co-operation of state and local health depts. and Army authorities obtained. Milk from outside sources accepted only when produced on milksheds operating under U.S.P.H.S. Milk Ordinance provisions. *Water Supply and Sewerage.* War and Navy Depts. cooperated with state health depts. and U.S.P.H.S. re provision of water supply and sewerage facilities for cantonment areas. In most cases plans submitted to state health dept. for approval before constr. Similarly, U.S.P.H.S. first obtains views of said dept. on water supply and sewerage facilities for air fields proposed by Engr. Corps. Cincinnati Stream Poln. Investigations Sta. of U.S.P.H.S. prepared pamphlet, "Notes on Basic Design Data for Emergency Water and Sewage Treatment Plants in Areas Affected by Natl. Defense Program." *General Sanitation.* In May, '41, U.S.P.H.S. prepd. "Sanitation Code for State or Local Adoption," at request of state and territorial health officers conference. Covers san. control of water supplies, sewage, ind. wastes, excreta, garbage and refuse, swimming pools and bathing places, milk and its products, frozen desserts, eating and drinking estabs., habitable bldgs., tourist, trailer, cabin, and constr. camps, and others. Usually, new local health organization in defense area first dets. enforcement powers available to effect recommendations. Frequently results in conclusion local ordinances necessary to avoid insanitary fringe or "mushroom" developments. Time prevents more desirable method, securing good gen. sanitation by educational methods. Above code intended to supply basic information needed. *Military Maneuvers.* Co-ordination of related activities of authorities in several agencies described.—*Ralph E. Noble.*

Chemical Poisoning of Municipal Water Supplies. HAYWOOD M. TAYLOR. Am. City **57:** 5:46 (May '42). Chem. agents which may be used for poisoning water supplies are classified in 6 groups: (1) heavy metals, including lead, arsenic, mercury, antimony, selenium, tellurium and others which are generally highly toxic, cumulative and are excreted very slowly; (2) cyanides, which are toxic in high concentrations but unstable even in air; (3) org. arsenicals, generally non-toxic except those used in war gases; (4) org. compds. such as phenols and cresols probably for use principally as taste-producing substances in making water unpotable; (5) alkaloids and some glucosides, including colchicine, nicotine, strychnine and digitalis, which are extremely toxic; (6) war gases which, with the exception of chloropierin can generally be rendered innocuous by hydrolysis or chem. treatment. General testing procedures include examn. for variations in color, taste, odors, pH, alky., salt content, chlorine demand and oxygen consumed, reaction of Cu in water, reaction of KI in presence of H_2SO_4 and spectroscopic examn. of solids after evapn. Probability of poisoning remote because of large quants. chem. required, their cost and regulations governing their sale. Best protection careful guarding of supply and careful examn. of routine anals.—*F. J. Maier.*

Running Water Clinic: Defense Aims. ANON. Elec. World **88:** 2:83 (Feb. '42). Applied on larger scale, running water means more productivity in food products, and release of power for other defense work and fire protection. Large nos. of small elec. pumps with carefully charted local water supplies of utmost importance in incendiary raids. Small amt. of water thus thrown on incipient fire worth tens of thousands gal. few min. later. Clinic included discussion of: wells and locations, water heads and resistance, irrigation and applications, domestic systems from health viewpoint, maint. and service, controls and wiring. Kind of pumps and use application listed. In choosing well sites, farmer should consider: health and sanitation, convenience, hydraulics, abundant supply. Specifically, 50′ depth considered sufficient for well penetrating hard-pan. Good concrete or tile curb around top will exclude surface water. Site selection should take into acct. accessibility by drilling rig for initial drilling or subsequent repairs, strategic location for fighting fire, and need for distance between well and pump site not to exceed 30′ to 60′. For irrigation, should locate well near source of elec. supply to save copper cost and near center of irrigation tract. Located in low spot, generally old river bed, water usually nearer surface than surface indicates.—*Ralph E. Noble.*

The Impact of the War Upon Public Utility Finance. FERGUS J. MCDIARMID. Pub. Util. Fort. **29:** 663 (May 21, '42). New capital funds for utility plant constr.; how will demand be met, effect of war on market for bond issues, refunding, tax exemption, should revamping of utility capital structure continue? Questions plaguing management and investor. In wartime, priorities are controlling factors in matter of new capital requirements. Our fortunes in this war directly related to vol. of energy which can be shifted to the war effort. As long as war lasts, dominant considerations influencing bond market will be financial requirements of natl. govt. Experience of both Great Britain and Germany is that utmost that can be derived from taxation is 40% of requirements, balance to be met from real savings or inflation. In Britain all refunding forbidden for first 15 mo. of war, later permitted under limitations. In past, life insurance companies large buyers of utility bonds, this money represents real savings. Insurance companies now will doubtless be under great pressure, moral or otherwise, to buy govt. bonds. Govt. recently sold 2½s due in about 30 yr. at par, going at a premium. During last war, rate rose with passage of time. Now, apparently different forces at work; on one hand enormously expanded national money incomes, on other tight system of rationing and price control prevents spending. Result, large money savings and great liquidity which has made possible govt. borrowing at pro-

gressively lower rates. Heretofore, bond interest paid by publicly owned utilities has been tax-exempt, this seems rather likely to be brought to an end by present crisis. In forthcoming crisis, best brains of the industry will be needed to make the best possible use of existing physical plant. Intolerable if such brains turned aside from solution of vital operating problems, to financial or regulatory matters which can be postponed into less critical times.—*Samuel A. Evans.*

Wartime Accounting. GEORGE N. FARRAND. J. Accountancy **73:** 401 (May '42). Statements in light of present conditions, future events will modify. Expect that soon more than half of country's productive capac. devoted to war. Production authorized and regulated by contracts. Fixed price contract now being replaced by more flexible methods. President granted power to requisition property, without recourse to contract procedure. President may authorize any govt. dept. to enter into contracts and into amendments or modifications of contracts heretofore or hereafter made, without regard to the provisions of law. Contracts in 3 groups: construction, facilities and supplies. Negotiated contract replacing competitive when latter impracticable, claimed to aid smaller mfr. "Letter of intent" authorizes production of needed supplies, with understanding contract will subsequently be made. "Emergency plant facilities" type of contract arrangement whereby government agrees to reimburse contractor for special emergency facilities constructed. Many variations of foregoing, subcontracts generally follow same variations as prime contracts. Std. contracts varied, specific terms of each should be investigated. Navy and Army depts. authorized to make advance payments on contracts. Although use of private funds preferred, loans to contractors authorized. In cost-plus-fixed-fee contracts, records of costs mandatory. Such records sole basis of reimbursement. Costs allowed and amts. vary with different depts. Some contractors no doubt made substantial profits, but much of adverse publicity against contractors entirely unwarranted. Govt.'s labor policy on war contracts outlined recently by WPB Director of Purchases, who stated contracts would not ordinarily be awarded to prospective contractors who have violated Wage-Hour Law, Walsh-Healey Act or Natl. Labor Relations Act. War program may cause certain laxity in acctg. stds., but exacting reporting and auditing requirements of war contracts should increase accountability of business during war period. Second Revenue Act of 1940 provides for complete amortization of emergency facilities for tax purposes over a period of 60 mo. Emergency facility defined as "any facility, land, building, machinery, or equipment or part thereof." WPB announced that mfrs. shall submit monthly reports on progress of war production and speed of conversion thereto.—*Samuel A. Evans.*

PUMPS AND PUMPING

Visual Experimentation With Centrifugal Pumps. HOWARD L. COOPER. The Engr. (Br.) **172:** 278, 395 (Oct. 24, Dec. 5, '41). Paper concerns model study in connection with 28" dredger pump. Model scale of 1:6 selected. Volute constructed of heavy pyralin mounted in rigid cast-aluminum frame. Impellers consisted of heavy pyralin shrouds, mounted on cast-aluminum spiders, keyed to pump shaft. Velocity measurements made with modified Iowa type pitot tube. 8 sections selected for velocity observations. Two or more openings provided in each section for insertion of pitot tubes. To obtain permanent records of flow conditions within pump, suitable photographic equip. developed for both still and motion pictures. Ultra high-speed camera coupled with stroboscope of extreme power and frequency, with flashes in order of 0.00001 sec. Flow conditions generally of complicated nature, subject to violent fluctuations and changes, making accurate description dif-

ficult. Comparison of flow conditions within impeller and eff. data leads to assumption that extent of deadwater zones within impeller has pronounced influence on relative eff. of impellers. Phenomena brought to light are existence of large deadwater areas within impeller and consequent existence of extremely high velocities over small percentage of cross-sectional area within impeller. Phenomena existent also in conjunction with fluid flow through bends in pipes and conduits resulting in extensive energy losses. *Discussion.* G. URE REID: Doubtful if "deadwater area" correct expression to use as it is considered that internal circulation may occur in this space. Stroboscopic study of movement of rubber balls in pump provides three facts which may be difficult to reconcile with orthodox textbook theory: (1) ball can remain in impeller for several revolutions; (2) can recirculate also around volute; and (3) ball can move inwards from volute and reenter impeller. OWEN A. PRICE: Rubber balls circulated were of "specific gravity slightly lower than that of water." Hence, behavior of balls does not truly represent behavior of water. Might have been shown if movements had been checked by repeating tests with slightly heavier balls.—*H. E. Babbitt.*

The Flow Through Centrifugal Pumps. G. URE REID. Engineering (Br.) **152:** 101 (Aug. 8, '41). Textbook theory of centrifugal pumps assumes that fluid must approach impeller channels radially, must fill them completely, and must be discharged uniformly around outer circumference; but not generally recognized that this applies only to impeller having infinite no. of infinitely thin vanes, operating on frictionless fluid. Introduction of friction materially modifies uniformity of discharge. Fact was developed by expt. designed to test whether fluid did utilize full channel area provided. Pump employed fitted with impeller of built-up type, from which shroud could be removed. Walls of channels coated with thick paint and, while paint still wet, pump run. Unexpected flow markings left on wet paint. Realized that markings indicated "creep," from region of high pressure along leading edge of a vane to region of low pressure along trailing edge. Difference between conception of fluid flowing in channels and vanes being driven through absolute streams shows itself in several ways: (1) tests demonstrate that head, quant., and eff. reduced if pre-rotation permitted; (2) encourages some modern authors to advocate allowance for pre-rotation up to as much as 50% of tip speed, with object of reducing relative velocity, though unfortunately addnl. area provided to pass quant. at reduced velocity not utilized; (3) it has led one authority to limit relative velocity, for max. suction effect, to 12 fps.—if rule applied to speeds above 15 to 20 fps. provides channel areas out of proportion to requirements; and (4) effect of friction due to wetted channels tends to increase head. Vanes tested were in single-inlet, central-suction, volute-type pump. Textbooks, when dealing with conditions in volute, refer to shock at entry. In fluids with viscosity equal to that of water, resistance to shear negligible. Crude indicator showed that absolute stream leaving impeller continues outward until reaching surface of volute. Divides, then, into two paths which flow in right-hand and left-hand spirals around volute. Therefore, only losses appear to be due to eddy formation and skin friction. Various investigators of hull friction have towed planks through still water. Mech. energy dissipated in such expts. entirely lost in eddy formation and skin friction. Only difference between this expt. and case under consideration is that plank has been replaced by a bent vane, and still water by moving stream. Essential to remember that vanes are moving through absolute stream; no other view of conditions that will conform to textbook theory that movement in channels relative.—*H. E. Babbitt.*

Air Chambers in Centrifugal Pumps. W. L. BOERENDANS. Gas- u. Wasser. (Ger.) **83:** 605, 659 (Nov. 30, Dec. 14, '40). Three methods for calcn. of water hammer pressure when air chamber on line given. Two methods assume water

and pipe line non-elastic, whereas third considers elasticity. All three give similar results for reduction in pressure, but vary more or less in calcd. superpressure, depending on size of air chamber. All calcns. show that use of air chamber generally causes no increase of pressure rise due to water hammer, but may do so. Does, however, reduce pressure drop. If air chamber equipped with check valve which allows only flow of water from air chamber into pipe and closes at moment velocity of flow zero, high pressure also limited to opposite amt. of reduced low pressure. Small hole to be provided in check valve to allow partial refilling of air chamber with water.—*Max Suter.*

The Pneu Pump. ANON. Wtr. & Wtr. Eng. (Br.) **43:** 272 (Sept. '41). Recently patented invention consists of simple pump with but one moving part, inlet flap valve. Can pump any type of fluid, with capac. up to 100 gpm. (Imp.), with heads up to 50′. Pump actuated by compressed air. Body consists of enclosed cast-iron or steel vessel, toward bottom of which is inlet flap valve. Pipe conveys compressed air to vessel and vertical pipe carries liquid away. Inside vessel and coupled to discharge pipe is seal pipe which controls cycle of operations within vessel. When seal pipe open, air entering vessel escapes to atmosphere giving practically atmospheric pressure inside vessel. Since vessel submerged in sump, water enters through inlet valve and gradually rises. Water flows over seal pipe and forms trap, preventing escape of air, which then displaces water through delivery pipe. Water level in seal pipe falls coincident with that in main vessel until bubble of air can escape around U-bend of seal pipe. Column of water in delivery pipe thus lightened and air escapes quickly, driving before it all water in pipe. Vessel again opened to atmosphere and cycle repeated.—*H. E. Babbitt.*

A Turbine-Driven Pumping Installation. ANON. Wtr. & Wtr. Eng. (Br.) **44:** 33 (Feb. '42). Interesting example of adaptability of self-contained type of turbine provided in recently completed water supply scheme involving equip. of two pumping stations, one steam-driven and one elec., both forming part of same pumping system. In steam station are installed 4 turbine units, each driving pump and generator coupled in tandem. Power from generators supplies pumping station 1¼ mi. distant. Turbines, of impulse type, designed for inlet steam at 295 psi. 670°F. and run at 6,000 rpm. Reduction gear has speed ratio of 6,000 to 876 rpm. Main pumps two-stage with approx. capac. of 7,650 gpm. (Imp.). Each condenser has cooling surface of 1,380 sq.ft. and requires 1,250 gpm. (Imp.) cooling water. In elec.-driven station main units consist of 3 vertical type Worthington-Simpson pumps of approx. 7,650 gpm. (Imp.) capac., driven by Metrovick vertical type 650-v. d-c. motors, each of 380 hp., and running at 732/873 rpm.—*H. E. Babbitt.*

A Large Steam Pumping Plant. ANON. Wtr. & Wtr. Eng. (Br.) **43:** 319 (Nov. '41). During last few months new pump engine installed at important water works in south of England. Installation consists of vertical triple-expansion condensing fly-wheel engine direct connected to 3 vertical single-acting plunger pumps. Reheater receivers provided between steam cylinders. Condenser of surface type on suction pipe to main pumps. Engine designed to take steam at 250 psi. superheated to 606°F. Total capac. of 2 pumps, 80,400 gal. (Imp.) per hr. against total head of 683′. Steam consumption guaranteed was 9.55 lb. per pump hp. per hr., but on actual test figure improved.—*H. E. Babbitt.*

Installs Pump—Motor 664 Feet Below Ground Surface. ANON. Ry. Eng. & Maint. **37:** 4 : 280–1 ('41). From 1890 to '07, Chicago, Burlington and Quincy R.R. obtained water supply for its terminal at Gillette, Wyo. from well 865′ deep with working barrel and steam head. From '07 to '38 reservoir supply, not dependable during dry weather and water of which was hard, used. New well 852′ deep installed with 177′ of 4″ and 5″ red silicon brass No. 30 screen gravel packed in lower 10″ slotted casing. A 12-stage,

10″ submersible type centrifugal pump with 40-hp. motor selected to avoid trouble from long shaft. Pump setting 664′ below ground with 4″ and 5″ discharge column. Pump operating continuously since Oct. 1939, pumping 80 gpm. with no trouble reported except one temporary power failure.—*R. C. Bardwell.*

Pumping Capacity of Cofferdam Pumps Increased. Int. Eng. **81:** 23 (Jan. '42). Capac. increased by attaching siphon to discharge extending over cofferdam to water level of waste, thus reducing net effective pumping head. Where cofferdam foundations porous, well points installed and connected to a header attached to suction pipe of a pump. Points generally 20′ long with nozzles to jet their way further into ground.—*Ralph E. Noble.*

Installation and Maintenance of Motors and Controls. H. V. Crawford. Sew. Wks. Eng. **13:** 10 (Jan. '42). [Ed. of Sew. Wks. Eng. emphasizes importance of this article to sewage plant operators in terms of national defense economy. Abstractor considers it of equal value to water works operators.] Very heart of modern water and sewage plants is their elec. equip. Before installation, highly important to get complete information on required care and maint. of elec. equip. for given class of service and location. Buy that which requires least attention. Proper maint. of motors highly essential to prevent shut-downs, especially without switch-over equip. Most important point, have definite program for inspection and test of insulation on motor coils. Frequency detd. by severity of operation. Inspect motors in damp, gaseous, or dusty atmosphere at least twice a yr.; in open, they should be of weatherproof constr.; subjected to dust or snow, totally enclosed, especially when operated part-time. Proper procedure, measure motor installation resistance of stator winding with installation resistance meter. If reading less than rated voltage divided by (0.75 × hp. rating) + 1,000 megohms, should remove and dry out with temp. under 90°C. until measured resistance again const. May dry by passing low voltage current through windings. Always follow above procedure in starting new motors, especially those in open. Failures other than from moisture usually due to dirt, oil or grease. In these cases, clean with low pressure compressed air or preferably with vacuum cleaner suction. In dusty locations, completely remove motor to remove dust with soft brush followed with carbon tetrachloride. After drying windings, as described above, while still warm, paint or spray with best type varnish. Dip small motors. Redry 1 to 6 hr. Poor condition windings may require 2 or 3 coats. Keep commutator or collector rings clean with polished surfaces. Prevent collection of dirt, carbon or copper dust between segments or on shaft between collector rings. Bearing inspection and maint. important. Every motor designed with certain gap between starter and rotor. If tapered air-gap gage shows less at any point than specified min. values, replacement of sleeve bearings indicated. Ball bearing motors indicate trouble, become inoperative with small wear, before any change in air gap. Operating conditions det. oil or grease changes and/or cleaning of bearings. Check thermal protection devices frequently to prevent heating from overload, poor ventilation or high resistance ground. Seal all joints of totally enclosed or splash proof motors to prevent water seepage through windings, using graphite to facilitate subsequent disassembly. To prevent deterioration of insulation in motors used infrequently, plan heated room or provide small heat with heaters in the motors during winter mo. Wiring and installation of one control system applicable to motors to reduce moisture absorption, described. Involves current flow through windings, heating directly and applying it where most effective, when motor not operating. Small transformer in enclosing case provides warmth for latter, protecting control from moisture accumulation. First consideration in control equip. maint. to provide operating force with complete instruction books and wiring diagrams for every piece and circuit. Necessary spares and complete list of parts should be available; also instru-

ments for checking voltage, current, resistances. Control should be installed in separate, dry, warm room free from corrosive fumes; separated, when possible, from pumps and motors with tight wall having sufficient glass space for viewing control board. Exceptions discussed. In control equip. maint., essential to prevent accumulation of dirt, oil or water. Carry stock of protective paints and proper insulating varnish. Inspect and paint control parts 2 to 4 times yr. Operate and adjust moving parts by hand to assure proper line up. Check and adjust all relays, particularly those with bellows or dashpot attachments. Certain types oil required. Operate all circuit breakers or contactors by hand to assure normal clearance and free working. Watch adjustment, filing and renewal of tips. Clean and check contact armatures for free working and parallel contact surface. With small ammeter check current required to operate same. If excess current required, check air gap and test all moving parts for friction. Inspect pigtail connections closely. Seal instruments from dirt and moisture, checking accuracy at least yearly. Float switches governing automatic start or stop of pumps should be watched as carefully as similar apparatus above. Final warning and special emphasis made to prevent elec. spark causing explosion to wreck plant or injure persons.—*Ralph E. Noble.*

Silent Sentinels of Service. PAUL LIPPERT. Eng. News-Rec. **126:** 959 (June 19, '41). Use of control and recording devices for promoting eff. in pumping station operation discussed. Continuous record of performance as shown by charts provides ultimate in valuable operating information. Often requires much more time to locate fault than to remedy it, and assistance given by instantaneous or charted records in such work can hardly be overestd. Suction well el., pump suction and discharge pressures, and vol. pumped must be accurately and continuously measured. When prime mover is motor and station small, any acceptable type of circuit breaker usually provides ample protection. Relays desirable but not imperative in small plants. Proper use of indicating wattmeter gives instant knowledge of impending or developing faults and reduces probability of motor damage. In large stations, overload, under-voltage, and, at times, differential relays necessary; and in addn. to wattmeters there should be voltmeters and ammeters. Modern switching and circuit opening devices also required. With up-to-date elec. control arrangement and competent operators, serious damage well-nigh impossible. No part of pumping station practice more advanced in equip. for regulation and control than boiler plant. Efficient burning of fuel most important. Instruments can be most economically and correctly serviced by their makers.—*R. E. Thompson.*

DISTRIBUTION SYSTEMS—CONSTRUCTION AND MAINTENANCE

The Welding of Piping. ARTHUR N. KUGLER. Heatg. & Ventg. **39:** 5:55 (May '42). Weldable pipe materials grouped as ferrous or non-ferrous. Almost all iron and steel pipe of A.S.T.M. specifications as A53, A120 and A106, etc., weldable, provided carbon content <0.25%. To weld higher carbon steel, preheating essential to avoid cracking in and adjacent to weld deposit. Post heat treatment also advisable here. Generally, alloy steels weldable with filler material of same anal., but with carbon <0.25%. A.S.A. issued new stds. for pipe dimensions (Wrought Iron and Wrought Steel Pipe, B36.10, '39). Fundamental basis, group of pressure ratings known as "Series." Classifications listed. With non-ferrous piping, copper, brass, aluminum, etc., common practice to use same dimensions and wt. designations of steel piping. Precautions: To weld copper pipe, best to use deoxidized in lieu of electrolytic copper if max. strength required. To weld brass pipe, avoid that contg. >0.5% lead. Latter, in brass, in relatively free (non-alloy) state, "sweating" out when welding heat applied, defying fusion. Brass and copper tubing frequently welded, particularly in larger

sizes. Development of sweat type socket fittings using low temp. brazing alloys (silver solders) greatly simplified operation and largely displaced welding, especially in smaller diams. Selection of joint design for welding piping limited by fact that back and inside inaccessible. Thus, for thin pipe and tubing up to $\frac{5}{32}$″ wall thickness inclusive, sq. groove butt joint generally used. For $\frac{3}{16}$″ and greater thicknesses, necessary to prepare ends using simple bevel, or more elaborate U- and J-grooves. Thicknesses up to $\frac{1}{2}$″ or $\frac{3}{4}$″ welded by oxyacetylene or metal arc processes with simple bevel, using single vee-groove butt joint. Industrial std. bevel angle $37\frac{1}{2}°$ providing 75° vee. Avoid all other bevels (45° or 30°) to save extra cost of mill preparation. These basic joint designs cover bulk of pipe welding operations for low and med. pressure systems. Modern power plants use higher pressures and temps., thus requiring heavier wall pipe as much as $2\frac{1}{2}$″ thick, or more. Generally arc welded although oxyacetylene equally applicable. For former, single U-groove butt joint yields best and most economical results. Less weld metal required and arc on root pass better controlled. For latter, single vee-butt joint with 30° bevels, 60° vee preferred. In arc welding power piping joints, backing strips (strips, chill rings, liners) at root of vee definitely advantageous to insure thorough root fusion and permit using larger electrodes and faster welding speeds. Chill rings not helpful in oxyacetylene welding—reflect back heat, hamper sound root fusion and retard welding speed. Their use justified only where internal protrusions must be of predictable nature to meter fluid flow as in superheater tubes. Fillet weld used principally on bell and spigot, and socket type joints. Former used mainly on brass and copper tubing. Braze-welded joints may be used on steel, galvanized iron, brass, copper. Simple open single vee-butt joint preferred. To provide max. bond strength between filler and braze metals, 45° bevel, 90° vee used. Lap or seal type joint used particularly on brass or copper tubing, less so on stainless steel. Strength depends on brazed connection.—*Ralph E. Noble.*

The Case for Welded Fittings *vs.* Miter and Intersection Welding. G. F. SHERMAN. Heatg. & Ventg. **39:** 3:42 (Mar. '42). Engrs. responsible for design, operation and maint. of piping sometimes must choose between factory-made welding fittings and fabrication of elbows, tees, reducers and caps by welding on job. Strength, eff. and economy must be considered. Difficult, if not impossible, to achieve full pipe strength without using properly designed welded fittings, reinforced against addnl. stresses imposed by shape. In elbows fabricated by miter welding, bursting stresses extremely high in crotch section. Even more serious is mech. stress caused by line movements from temp. changes. Highly concd. at welds. Regarding strength, intersection welding for branch connections, in lieu of properly designed welding tees, more unsound than miter welding. Under bursting pressure, highly concd. stress exists around opening in run pipe; believed max. at intersection of top with wall of branch. Ineff. through loss of head by frictional resistance of pipe and fittings offset by using mfrd. welding fittings. Latter, properly designed, repay own cost in short period. Cost data comparison made. Reasonably safe to predict mfrd. welding fittings will completely replace miter and intersection welding and other substitutions of fabrication for fittings.—*Ralph E. Noble.*

Repair of Small Steel Water Mains. ANON. Wtr. & Wtr. Eng. (Br.) **43:** 339 (Dec. '41). Trouble in making joints when repairing old steel service mains of small diam. and using normal bolted type joints has been partly overcome by insertion of length of asbestos-cement or c-i. pipe of equal diam. and use of bolted detachable joints as supplied with asbestos-cement pipes. Considerable time saved in repair of pipes as no double calking of deep sockets required. Once main cut and insertion of correct length supplied, repair matter of few minutes.—*H. E. Babbitt.*

Use of Wicking in Pipe Thread Joints. W. F. SCHAPHORST. Heatg. & Ventg. **39:** 5:26 (May '42). Conditions equal, better

to lamp-wick brass threads to forestall leaks. Wicking and compd. make best joints. Less time required to wick iron pipes than retrace threads with new taps and dies to insure tight fit. Some do both. German mechanics wick both iron and brass threads.—*Ralph E. Noble.*

Research on Cast Iron. ANON. The Engr. (Br.) **172:** 360 (Nov. 21, '41); Engineering (Br.) **152:** 414 (Nov. 21, '41). Program of British Cast Iron Research Assn. includes investigation of native iron ores. Most readily accessible English ores phosphoric in character. Three lines of investigation being followed to extend utilization of phosphoric iron in foundry: (1) to increase production and augment use of refined irons made, in part, from phosphoric material; (2) to employ cast iron contg. phosphorus to highest limits set by considerations of mech. strength and soundness; and (3) in dephosphorization of phosphoric pig and scrap. Work done on cast irons contg. very fine graphite structures postponed. Work on detn. of non-metallic inclusions in pig iron and cast iron continued and methods involved being applied to representative series of British pig irons. Researches on properties of ingot mold material at ordinary and elevated temps. proceeding and work carried out to extend life of ingot molds proving of great service under present conditions. —*H. E. Babbitt.*

Standardization of Pipes in the Netherlands. J. H. SCHNEIDER. Water (Neth.) **25:** 177 (Oct. 31, '41). Normalization leaflets of mains commission pertaining to inspection requirements for thermal zincification of steel and c-i. pipes; thermal zincification of steel and c-i. appendages; and appendages and parts for san. purposes and replacements. —*Willem Rudolfs.*

Thawing of Frozen Pipes by Electricity. L. A. FERNEY. Wtr. & Wtr. Eng. (Br.) **43:** 310 (Nov. '41). No economical, rapid and safe method of thawing pipes except by elec. Current necessary for thawing purposes relatively large—about 300 amp. Must be readily adjustable within wide limits. Voltage low—12 to 18 v.; thus, power consumption small. Method consists of connecting ends of frozen pipes to terminals of source of power, in series. Since voltage drop across pipe, or amperage necessary, impossible to predict, elec. supply must be carefully considered. Generator or transformer with "drooping characteristic" necessary. Drooping characteristic machine has definite voltage at terminals when no current being supplied. Fortunately large nos. of such machines supplied for arc-welding plants. Thus, many std. makes of arc-welders suitable for pipe thawing. Suitable if they have following characteristics: output of at least 300 amp.; open-circuit voltage not exceeding 60; either possess wheels or are light enough for easy transportation; weatherproof; have ammeter built into or mounted on machine. Three general types of plants: (1) generator driven by internal combustion engine and mounted on pneumatic wheels; (2) motor generators; and (3) transformers. Auxiliary items required include cable, whr. meter and switch fuse. D-c. may produce undesirable electrolytic action or generation of gases or chems. in water mains. A-c. commends itself. Elec. thawing safe since voltages low, yet essential that electrician be employed for connections. Questions of who is to effect primary connection, how charges to be arrived at, etc. must be settled in advance. Secondary connection must be made at nearest convenient points to frozen pipe section. Such points may be fire hydrants, street service cocks, etc. Several non-metallic packing materials in use for making joints. Before proceeding with thawing, well to know what joints used, because may so increase resistance as to burn or melt pipe at that point. Also necessary to det. whether any elec. system grounded by connection to frozen pipe. Water meter in circuit should be removed. Ice in meter may be thawed with gas flame. During thawing, cocks must be left open to see when process completed and to prevent generation of steam. When thawing starts, isolating switch of welding machine closed and amperage gradually increased from low start. Once reasonable current flow

adjusted, left on for several minutes. Lead pipe will seldom carry more than 150 amp. safely, while 100 amp. deemed safer figure. Table gives rough idea of currents and times necessary to thaw 100′ length of pipe of various diameters:

Pipe Diam., *in.*	Power required, *amp.*	Time required, *min.*	Power consumption, *kwhr.*
3/4	150	5	1/4
1	200	8	1/2
2	300	20	2
3	400	60	8
6	400	90	12

Total cost accurately estd. only after considerable experience.—*H. E. Babbitt.*

Preheating Water by Electricity for Protection of Submarine Mains From Freezing. Herman Burgi Jr. J. Me. Water Utils. Assn. **17:** 42 (Mar. '41). Description of methods of heating public water supply to prevent freezing. Heating done in winters of '29–'30, '30–'31 and '31–'32 on water supply of Peaks Island near Portland, Me. Rates of flow varied from 17 to 42 gpm. in 6″ main, 2,500′ long, laid on ocean floor. Because of high salinity, ocean water attained temps. of 28° without freezing. Calculated 23.4 kw. required to heat these winter flows, 30 kw. actually installed. 5-kw. immersion heaters used, two installed in each of three 6″ x 6″ x 10″ x 10″ all-bell crosses standing the 10″ ends vertically with plugs on both ends. Cost of installation with pit, manholes, switches, etc., $956. Heaters turned on as salt water reached temp. of 32°F., current used varied between 30,000 and 43,000 kwhr. Installation successfully used for 3 winters, then no longer needed when new 8″ line laid in 5′ trench.—*Martin E. Flentje.*

Cleaning Pipe Without Interrupting Service. Anon. Compressed Air Mag. **46:** 6543 (Sept. '41). Rotary pipe crawlers are specially compounded rubber balls, covered with snap-on or -off chain mesh, 5″ to 30″ in. diam., after air inflation. Normal practice to send ball through pipe twice. First, after partial inflation to bring chain in contact with top. Second, after partial filling with water, causing ball to scrape along bottom. Used to remove incrustations, roots, or other debris from concrete, lead and wood-stave or other pipe lines.—*Ralph E. Noble.*

Methods for Cleaning Sewers and Underground Pipe Lines. R. E. Wachter *et al.* Bul. Am. Ry. Eng. Assn. **43:** 427-93 (Nov. '41). Method for cleaning of underground water lines will depend upon size of pipe, type of incrustation and water pressure available. Pressure-operated scrapers and cutters mentioned, and rotary process with flexible steel rod. Chem. methods involve too great expense except for small and relatively short lines.—*R. C. Bardwell.*

Cleaning a Large-Sized Pipe Line in Place. W. H. Mead. Civ. Eng. **11:** 728 (Dec. '41). During Jan. '30, Salt Flat Water Co. formed by oil producers of Salt Flat Field at Luling, Tex., to dispose of salt water produced along with oil. Salt water high in carbonates and hydrogen sulfide gas. $CaCO_3$ deposited on inside of pumps and pipes, so restricting flow of water that something had to be done. Deposit thickness measured with welding rod passed into pipe through cocks. Greatest restriction near pump station where diam. remaining open was only 8″ in 20″ pipe. Principle of cleaning machine is milling away of deposit by tool in end of flexible rod rotated at about 800 rpm. Tool is round steel bar 18″ long to which are attached 6 chains. Tool automatically centered by centrifugal action of twirling rod. On 10″ and 12″ lines, length of 2,000′ per day cleaned without trouble. Total cost of cleaning was: for 10″ pipe, 14.5¢ per ft.; for 12″, 21.6¢; and for 20″, $1.06 per ft.—*H. E. Babbitt.*

Rejuvenation of Existing Pipe Lines by Cleaning and Cement Lining in Position. Bruce Harkness. Tex. W.W. Short School **22:** 58 ('40). In Tate process, which is described, 350′ sections of main first cleaned by Tate cleaning machine, obtaining avg. of 12 tons per mi. of corrosion products. Then mixture of 2 parts of sand and 1 of portland cement poured into pipe and, by means of plunger, spread uniformly over pipe. Lining "Mandrel" fastened to cable and

hauled through pipes compacts mortar on walls of pipe at pressure of approx. 130 psi. in thickness varying from $\frac{1}{8}$" to $\frac{3}{4}$".—*O. M. Smith.*

Asphalt Protective Coating for Steel Water Pipes. A. H. BENEDICT. Eng. News-Rec. **128:** 327 (Feb. 26, '42). Extensive study at The Asphalt Inst., San Francisco, summarized. Two conditions prerequisite to corrosion: (1) metal must be in direct contact with corrosive environment; and (2) moisture and oxygen must be present. Protective coating, therefore, must maint. continuous membrane capable of excluding all corrosive agents. Studies clearly show that water absorption, as indicated by soaking test, not measure of amt. of water which will diffuse through bituminous film, and that amt. of water which can permeate intact asphalt coating not sufficient to support signif. deg. of corrosion. Furthermore, bituminous materials have been found to be much less permeable to oxygen and other gases than to water. Corrosive agent must find access to pipe by means other than diffusion and all-important requirement, therefore, is that coating should be continuous under all conditions. Causes of openings made before pipe is in service are: (1) bubbles due to inclusion of air or application of enamel to damp pipe; (2) contact between wrapping and pipe due to excessive tension in wrapper applied over hot enamel; (3) foreign material in enamel; (4) puncture by hard objects before enamel has cooled; (5) cracking by vibration during installation; and (6) peeling or slipping due to high temp. resulting from exposure to sun. Causes of openings made after pipe in service are: (1) puncture by hard objects in trench; (2) stripping by soil stress; (3) cracking due to low temp.; and (4) porosity caused by loss of water-soluble components. Tabulation given of results of tests to det. relative rating of 4 asphalt coatings. Basic requirements of Inst. specifications are: softening point, 220–260°F.; penetration at 77°F., 3–12 cm.; ash, 10–35% by wt. Other tests made refer to performance in service, i.e., sagging at high temp., cracking or disbonding at low temp., resistance to peeling, impact and soil stress, and soly. In regard to resistance to vibration, softer enamels usually superior, but unduly high penetration value results in increase in susceptibility to damage by hard objects and distortion under soil stress. As result of studies, specifications have been adopted for primary materials, enamel coating, application methods, wrapping with asphalt-satd. felt and performance-test procedures.—*R. E. Thompson.*

Ten Important Points on Valve Installation and Maintenance. FRED. C. ERNST. Heatg. & Ventg. **39:** 4: 25 (Apr. '42). Critical materials conservation concerns every plant engr. from commonsense, economy and patriotic standpoints. (1) *Before installing pipe*, clean inside thoroughly with air or steam. Unremoved scale, dirt or debris can damage valve seats. (2) *When threading pipe*, have threads of correct diam. and length. Too long threading may permit pipe to press against valve diaphragm or seat, distorting or destroying latter. (3) *After threading pipe*, brush threads well to remove chips, apply threading compd. sparingly to threads only, thus preventing excess from causing loose valve-seat. (4) *When installing pipe*, have line properly supported to prevent sag from springing valve bodies, resulting in leaks or valve loss. (5) *Before installing valves*, clean threaded end of screwed-end valves, and ports of flanged-end valves thoroughly. Open valves fully and flush with water, air or steam. Keep ports vertical and spindle horizontal. When clean, close valves tightly at once, before installation. (6) *When installing valves*, most important to have spindle vertical to insure tightness and increased life. (7) Detailed instructions given for installing globe and angle, gate, lift check, swing check, and Y or blow-off valves. (8) When pipe-and-valve installation completed, flush line with water or steam. When pressure and temp. have expanded metal, "follow" all bolts and nuts of pipe flanges and valve-bonnet joints; nuts on valve packing boxes. This action forestalls leaks and possible blow-outs at vulnerable points. (9) *If valves do not hold* tight, *do not* apply extra leverage to wheel, but inspect seat sur-

faces. Perhaps wrong composition disc used, or nick in seat. (10) *Valve maint.* strikingly reduced by periodic inspection, depending upon specific service conditions and incidence of valve operation. If seepage develops, redisc or regrind valve immediately. *Never use pipe wrench on valve.* Use hex, monkey or open-end wrench always. Proper regrinding procedure detailed.—*Ralph E. Noble.*

Unique Features Mark Design and Erection of Mammoth Concrete Water Tower. ANON. Concrete—Reg. Ed. **49:** 2 (Nov. '41). Reinforced concrete water tank (1 mil.-gal. capac.) completed at Fort Bragg, N.C. Inside diam. 70′. Height to water level 35′, with bottom slab of tank 85′ above foundation slab. Tank supported on 3 concentric reinforced concrete cylinders. Usual practice to support on braced columns. Inner cylinder 9″ thick, and id. 18′ 9″. Other 2 cylinder walls 8″ thick. Clear space between walls first and intermediate cylinders 13′ 2″, while clear space between walls of intermediate and outer cylinders 12′. Outer wall of cylinder coincides with wall of water tank above. Advantages: (1) lateral stability of structure of more than ample magnitude and equal in all directions; (2) complete distr. of vertical loads over foundation slab. Similarly, cylinders provide 3 concentric circles of support for very heavy base slab of tank itself.—*Ralph E. Noble.*

What It Takes to Be Earthquake-Resistant. ANON. Eng. News-Rec. **127:** 742 (Nov. 20, '41). Much progress made in making elevated tanks earthquake-resistant since Long Beach earthquake of '36 focused attention on problem. New 500,000-gal. tank built at Tucson, Ariz., airport one of best and most recent examples. Tank designed for lateral force of 0.1 gravity and has shorter panel lengths and heavier and more rigid cross-bracing than structure planned for vertical and wind loads only. Drawings show size of members in towers of Tucson tank and same tank with earthquake forces omitted. Increase in steel tonnage about one-third.—*R. E. Thompson.*

Exterior Ribs Feature Welded Tank. ANON. Eng. News-Rec. **128:** 614 (Apr. 23, '42). New 2.5-mil.gal. tank recently completed in residential section of Tulsa. Structure all-welded steel tank with exterior ribs to break up large surfaces and aid in supporting ellipsoidal dome and ornamental cupola. Tank 85′ in diam. and 77′ in height. The $\frac{3}{4}$″-steel bottom rests on 6″ reinforced-concrete slab increased at edge to form curb 2.5′ high and 1–1.5′ wide. Cushion of oiled sand, 2″ thick, placed over slab to provide uniform load distr. Seven 7.5′ steel rings varying in thickness from $\frac{3}{16}$″ at bottom to $\frac{1}{4}$″ at top used for side walls, while dome made up of $\frac{1}{4}$″ plate. Equally spaced around exterior are 8 hollow, U-shaped ribs of $\frac{3}{16}$″ plate, which extend 3′ beyond edge of tank, curved portions being bent to 1.5′ radius. One rib encloses 15″ overflow pipe. High-water line 60′ above base to allow lower 7.5′ of dome to be used for storage. Second rib encloses ladder leading to opening near top of tank. Tank painted white over red lead base, Al paint being considered undesirable since it would impart industrial appearance. Location of tank detd. by flow anal. of distr. system, using Hardy Cross method. Study revealed that distr. system had value of 120 for *C* in Williams-Hazen formula. Cost of structure $50,000.—*R. E. Thompson.*

Design of 2,500,000 Gallon Steel Reservoir for Tulsa, Oklahoma. D. A. LEACH. Southwest W.W. Jour. **22:** 10: 15 ('41). Standpipe is 85′ high, 60′ in diam. and capac., 2.5 mil.gal., with 1 mil.gal. above 40′ el. To relieve effect of unbroken, unsightly surface are 8 vertical ribs or pilasters, 3′ wide and 3′ deep, with curved outer face. Pilasters follow contour of shell and ellipsoidal roof, thereby breaking entire surface into 8 equal segments. Ribs meet at center of roof at compression ring surrounding cupola. No ornamentation is good design unless it serves a purpose. Vertical ribs serve as roof trusses, hanging roof plates from them. Roof plates are dished to ellipsoidal dome shape, pleasing to eye and reinforced on under side with curved beams to carry load to rib

trusses inside tank. No interior columns or additional trusses subject to corrosion. Roof load then carried through ribs into tank shell, and vertical portion serves as column to take roof load to foundations through shell. Each rib stiffens shell so that it is able to carry compression load as column. One of ribs used as overflow, another, to house vertical ladder and electric conduits, hiding fittings from outside. Surmounted by cupola housing, screened openings and vents and supporting airplane beacon light. By use of welded construction, entire outside of reservoir smoother and when painted will present pleasing appearance.—*O. M. Smith.*

Prestressed Concrete Water Tanks. ANON. Eng. News-Rec. **128:** 608 (Apr. 23, '42). Structurally unsound open reservoir in Council Bluffs, Iowa, being being replaced by twin 2-mil.gal. concrete reservoirs. One has been completed and second under constr. Both will be 236′ above level of town and will maint. pressure of 85-90 lb. throughout business district. Tanks have inside diam. of 106′, with height to overflow of 30′ and dome rise of 13.5′. Specifications permitted vertical joints only in walls. Prestressed steel banks placed around 15″ of concrete and covered with 4.5″ of concrete provide wall in which tension in concrete eliminated. Floor poured in concentric circles from outside to center, 7.5″ thick and with outer edge of 15″. Inner 15″ concrete wall consolidated with mech. vibrator and, when concrete had set, 74 round steel banks, $1\frac{3}{4}$″ thick, consisting of 10 rods each connected by turnbuckles, placed at intervals varying from 3″ c. to c. at bottom to 12″ at top, and prestressed by means of turn-buckles. Pilasters (18) in outer wall relieve severe lines of structure. Dome ring bearing directly on top of wall, separated by asphalt joint, placed in 1 pour and, before pouring dome, 9 steel bands prestressed around dome ring. Dome poured in 3 sections, starting from outside. All joints filled with mortar and entire water surface given several coats of metallic waterproofing. Wall has withstood static pressure of 30′ of water without leakage.—*R. E. Thompson.*

METERS

Water Supply. Measurement and Use. JOSÉ FRANCO T. HENIQUES. Rio de Janeiro (Braz.) (1942). 184-pp. book on subject of water metering in which modern European and Am. practices effectively summarized. After brief historical review, rational classification of available types of water measuring devices presented. In chapter on positive displacement type meters, mention made of fact that in spite of many superior features of nutating disc type meters, so popular in U.S., rotary piston type found better adapted to low flow measurements under reduced water pressure conditions. In general, Am.-made volumetric meters have not shown low flow precision of those of European mfr. Moderate friction losses in velocity type meters make their selection logical where larger, steady flows to be measured. This type, however, requires careful adjustment of moving parts if large errors are to be avoided. Where flow to be measured fluctuates within wide range, use of compd. meters indicated. Factors considered in selection of meters include chem. characteristics and price of water delivered; initial cost, ability to withstand corrosion, constancy of precision after long service, and low flow sensitivity of meters; accessibility of moving parts and their replacement cost. All parts should be protected against action of chem. substances in water and be able to resist abrupt variations in pressure. Strainers with openings smaller than 1 mm. and having net flow-through area not less than $2\frac{1}{2}$ times cross-sectional area of inlet pipe considered essential to protection of meters. Meter size depends on flow characteristics and available pressures. Definite adoption of given meter type should be made on results of performance tests when new and after several years of operation in distr. system; also on length of satisfactory service before repairs necessary. Meters requiring periodic inspection

oftener than from 3 to 5 yr., according to type, considered inferior and justifiable only when low purchase price offsets higher cost of maint. Accelerated test designed to det. effect of use on meter performance as follows: obtain characteristic performance curve of new meter; subject meter during 300 hr. or more to discharge equal to ½ capac.; obtain second performance curve to be compared with that of new meter. During test period meter should not be operated more than 12 hr. per day. Besides this fatigue test, meter subjected to static pressure test. Well-kept meter history records valuable aid in appraising relative merits of competing devices. Theoretical principles involved in water measurement with Venturi tubes and orifices discussed, and accepted practice for selection and installation presented. Hydr. and elec. devices available for recording flows measured by Venturi type meters described. Hydraulically operated devices suitable where distance between measuring unit and recorder does not exceed 150 m. Elec. transmission and telemetering employed when flow records must be instantly available at distant central station. Statistical data presented in section on water consumption shows that, in Am. cities, amt. of water used per capita from 2 to 3 times that of European cities. Consumption in principal cities of Brazil, although slightly larger than that in European localities, far below that of cities in U.S.—*J. M. Sanchis.*

Plastics for Water Meter Disks. JOHN D. PIPER. Modern Plastics. **19:** 8:68 (Apr. '42). Tests made to select commercially available plastics for water meter disks to function in hot water. Results show some market phenol-formaldehyde compds., including those of low sp.gr., resist deformation by moisture absorption or plastic flow, even at 100°C. Appear promising for water meter disks operated at elevated temps. Tests not made to det. their resistance to wear or effect on metal corrosion. As this type compd. used for water-lubricated bearings, however, believed resistant to wear as water meter disk material and not promotive of corrosion. Final evaluation necessary on disks themselves, but possible only after fabricators ascertain whether disks can be made to tolerances required at reasonable prices.—*Ralph E. Noble.*

Frost Protection of Rotary Meters. ANON. Wtr. & Wtr. Eng. (Br.) **44:** 37 (Feb. '42). In case of ordinary rotary meters, freeze-up can damage them more or less beyond repair, but installation of special Glenfield rotary meter, in which frost protection device incorporated, can avoid this danger. Device takes form of retaining ring located between index unit and cover of meter. On freezing of water in meter, ring yields and allows index unit to move upwards without damage except to ring. New frost rings should be fitted to meters as soon as possible after thawing.—*H. E. Babbitt.*

TUNNELS AND AQUEDUCTS

Pipe Connections for High Pressure Conduits for Water. HELLMUT GOTTING. Gas u. Wasser. (Ger.) **83:** 169 (Apr. 13, '40); **83:** 187 (Apr. 20, '40). Conditions for good connection are that tightness, stresses due to tension, bending or torsion shall be absorbed without causing leakage, and that the joint shall last as long as the pipe. Joints are grouped into elastic, stiff and bell and spigot types. Elastic joints are made tight by use of rubber rings, either rolled in between bell and spigot and held in place by a metal ring on the spigot, held in place between two flanged ends of the pipe which are bolted together, or pressed between bell and spigot by a screw ring threaded into the bell. Elastic connections cannot transmit length forces. Tees and elbows, therefore, have to be anchored. Stiff joints are formed by ordinary threaded connection or by welding of steel pipes. Several types of welded joints are shown, use depending on forces that have to be transmitted. Welded joints must be coated inside and out after welding, to protect the joint against corrosion. Coating is easy in large pipes,

but in small ones, must be applied inside by special methods of spraying or by nozzle welded into top of pipe through which coating is introduced. Welded pipes require expansion joints. In old lead joint for bell and spigot, jute had merely function of keeping lead from flowing into pipe. Lead had to render joint impervious and mechanically solid. As use of lead now prohibited in Germany, many substitutes are used. Tests on such substitutes consist of: (1) determination of pressures at which leakage occurs, at which joint material is pushed out and at which pipes are separated; (2) tests of mechanical strength of joint material; and (3) observation of joints buried in ground. Found that most substitutes can only act to furnish mechanical strength, density to be provided by jute, which is used saturated with bitumen or white lead. Excelsior with bitumen also found satisfactory. Jute when used to provide water tightness must be calked in thin layers. As substitutes for lead aluminum-wool, "Sinterite" (spongy iron with bitumen) and "Mundit" (seemingly a sulfur product) were found satisfactory. Metallic substitutes must be protected from water on inside and outside of joint, by bitumen. "Mundit" showed little adhesive power. —*Max Suter.*

Building Baltimore's Big Tunnel. JOHN J. HUNT AND BERNARD L. WERNER. Eng. News-Rec. **125:** 466 (Oct. 10, '40). Tunnel under construction from Loch Raven Dam to Montebello filtration plant is 7-mi. conduit with finished bore of 12′. For ⅔ length, tunnel is concrete lined and remaining 12,000′ is lined with continuous welded-steel plate, installed in 40′ sections. Total drop between 2 ends of tunnel is 110′ and shaft at filter plant is 165′ deep. Details given of drilling, mucking and lining operations. Bulges due to ground-water pressure occurred in steel plates after grouting. Length of bulges averaged 36′ and deflection, 15″. Bronze check valves (1″) installed in affected areas to permit infiltration of ground water when tunnel is unwatered. Steel pipe section was lined with 1½″ gunite. Steel pipe, 10′ in diam., installed in open cut, connects new and old tunnels. Pipe is encased in concrete and lined with bitumastic enamel. Capacity is 275 mgd. and cost of project about $5,400,000. Water can be supplied to filters by pumping if reservoir is depleted to extent that gravity head is insufficient to meet demand.—*R. E. Thompson.*

Pipeline Work in Rough Country. ANON. Eng. News-Rec. **126:** 602 (Apr. 24, '41). Illustrated description of laying of 59-mi. pipeline by Shell Oil Co. from Fall River to Waltham, Mass. Line 6⅝″ outside diam., 1,300-lb. hydrostatic test, seamless tubing with ¼″ walls. Initial pressure at Fall River will be 1,000 psi. Aerial surveys were employed in selecting route, which avoided developed areas, towns, open water and more difficult terrain. Bends frequent to go around larger trees and landscaped areas. Pipe fabricated in double random lengths (about 40′) and that to be used in bog areas coated in mill with ¼″ asphalt and wrapped with paper. About 10.5 mi. of line laid through bog areas. 2 river, 17 railroad and 97 highway crossings. Under main highways and railroads, pipe laid in 10″ casing jacked into position. "Stovepipe" method of welding employed, almost entirely above ground, pipe being supported above trench on timbers during welding. Trench 30″ deep.—*R. E. Thompson.*

"Breathing" in Steel Siphons Stopped by Thicker Pipe Metal. ANON. Eng. News-Rec. **126:** 469 (Mar. 27, '41). Replacement of 5 siphons on Los Angeles aqueduct made of ¼″ and 5/16″ metal with pipe made of ⅜″ plate contemplated for several years, partly as result of constant flexure in "breathing" and partly as result of gradual corrosion. Thinner plates not stiff enough to resist recurrent stresses caused by surge of water in upper ends of siphons, where pipe only partially filled. 3 of siphons replaced last fall and other 2 being replaced this spring. Other than repair of breaks, this is first major reconstruction done on 10 mi. of siphons since 233-mi. aqueduct placed in service 27 yr. ago. Contract price for 3 completed siphons, including excavation and backfilling and concrete

piers, $496,253. Welded joints, instead of riveted joints used on original siphons, being employed. Interior of pipe coated with coal-tar enamel at fabrication plant, except at ends, which are coated after welding. Exterior surface exposed to weather receives shop coat of synthetic red lead enamel, shop coat of synthetic white enamel and finish coat of aluminum paint. Pipe fabricated in 30′ lengths weighing about 8 tons.—*R. E. Thompson.*

New 31-Mile Pipe Line for Grand Rapids, Michigan. ANON. Am. City. **55:** 8:52 (Aug. '40). New water supply line from L. Michigan for Grand Rapids, Mich., involved mfr. of 163,100′ of 46″ reinforced concrete pressure pipe and its installation with needed appurtenances. Pipe was made near Grand Rapids at rate of 1,216′ (225 cu.yd. of concrete) per day, in 3 operations: (1) fabrication of steel structure; (2) pouring of concrete; and (3) curing and storage. All special pipes were made at field plant. Trucks delivered finished pipe to 4 construction gangs.—*Arthur P. Miller.*

Aqueduct Maintenance. F. C. MERRIELL. Eng. News-Rec. **125:** 325 (Sept. 12, '40). Brief discussion based on writer's experience in western Colo., where most municipalities derive water supply from mountains through long pipe lines. Reliable operation and effective, economical maintenance of such lines require variations in alignment which divide length into sections of somewhat uniform gradient. Entrance structures must be designed to reduce air to min. Neglect of this feature will inevitably result in throttling in certain sections and free flow in others, and will manifest itself as leaky rotting staves in wood pipe, reduced capacity in metal pipe and, in some cases, by phenomena like the "breathing" complained of in Los Angeles Aqueduct. In one line of untreated wood-stave pipe constructed by author, line has never failed to convey designed quantity of water during period of 11 yr. and maintenance has been less than $15 per mi. for whole period. Entrance structures were made as nearly perfect hydraulically as possible and free air vent was installed immediately below intake for each section. At each change of pipe size, both sizes of pipe were freely vented and water was occasionally passed through small, buried concrete tanks, where grade line permitted, to separate entrained and dissolved air and remove all free air. Only one form of vent is satisfactory—full size T-opening into full size pipe, carried above hydraulic grade. Siphons must be considered as individual structures and their air control problems localized. —*R. E. Thompson.*

Passing Faults in the Delaware Aqueduct. ANON. Eng. News-Rec. **127:** 150 (July 31, '41). Difficulties experienced during construction of New York's 85-mi. aqueduct, longest tunnel of all time, include water pressure up to 290 psi. and mud and muck were forced into tunnel in 1,000-yd. lots by inrushes of water. In selecting route, as many as possible known fault zones and areas of porous rock avoided but neither economical nor practicable to bypass all of them. Methods employed in overcoming difficulties described.—*R. E. Thompson.*

Lining the World's Longest Tunnel. ANON. Eng. News-Rec. **127:** 792 (Dec. 4, '41). Procedure employed by each contractor in lining New York's 85-mi. water tunnel described, thickness of lining for 3 sizes, 13.5, 15 and 19.5′ lined diam., being shown in fig. "*A* line" is min. clearance line within which nothing is permitted to project except satisfactorily spaced steel ribs without lagging; "*C* line," generally 5″ outside "*A* line," is line of effective avg. thickness within which no perishable material other than abs. min. of timber posts and blocking outside steel ribs is permitted to remain; "*B* line" delimits rock excavation and concrete to be paid for under normal conditions and is generally 13″ outside "*A* line." Concrete contains 2 bbl. cement per yd., natural sand fine aggregate and either gravel or crushed stone coarse aggregate. Tunnel driven and concrete being handled from 30 shafts, 300-1,550′ deep. Curing largely by spraying with hose.—*R. E. Thompson.*

Grouting Tunnel Lining on the Aqueduct. ANON. Eng. News-Rec. **128:** 19 (Jan. 1, '42). Grouting back of tunnel lining in Delaware Aqueduct being carried out to fill joints, cracks, fissures or other voids in surrounding rock, to render structure watertight and capable of resisting, without movement, water pressure in tunnel, which in places will exceed 500 psi. Grouting effected, using displacement pump connected to pipes left in lining, in 2 operations, first at pressures up to 100 psi. and then at pressures of 600 psi. or more. Low- and high-pressure grouting permitted when concrete lining in place 1 and 3 mo., respectively. Neat cement grout used except where dry packing has been placed or for special cases where large voids are thought to exist, in which cases find sand is added to mix. Amt. of grout used compared with that used in City Tunnel No. 2, built in '29-35, indicates newer methods of placing concrete leaves less than half volume of voids left by earlier placing methods. In 1 section, leakage reduced from about 70 to about 7 gpm. per mi. by grouting.—*R. E. Thompson.*

Key West to Have Fresh Water Aqueduct. ANON. Eng. News-Rec. **127:** 756 (Nov. 27, '41). Last obstacle in way of constr. of Key West Aqueduct removed recently when Fla. Supreme Court approved issuance of $1,750,000 in bonds by Fla. Keys Aqueduct Com. U.S. Navy will furnish $2,250,000 toward cost, and Com., $1,125,000. Aqueduct will extend from mainland near Miami to tip of Key West peninsula, distance of 134 mi. Line will be 18″ in diam. and will carry min. of 3 mgd., $\frac{2}{3}$ of which will be used by Navy and $\frac{1}{3}$ by civilian pop. Expected that project will be completed early next yr. Total cost estd. at $3,000,000, including pumping stations.—*R. E. Thompson.*

Placing Heavy Concrete Pipe Sections Into Difficult Position. ANON. Concrete **50:** 5 (Jan. '42). Concrete pipe water main (48″) run through reinforced concrete and steel tunnel under W. Orange branch tracks of Erie R.R. near Second River, N.J. All pipe installed from northern end with 7-ton chain hoist mounted on "A" frame, on 6″ steel tracks to temporary timber structure over excavation leading to tunnel. Hoist picked up 12′ length from wooden supports over "well" under upper tracks. Supports removed and pipe lowered on to steel carriage in excavation. Carriage ran on steel track into tunnel. Cable and winch dragged pipe through tunnel to proper point. "Dead man" on brace placed inside previously installed pipe, and steel bar fastened to far end of new pipes, utilized to close joints tightly. These joints rubber-lined. Cement used to seal joints after ends fitted, with grouting on outside. Pipe rested on temporary wood supports while being placed, then 30″ high brick pedestal constructed as permanent base. When line completed, Newark will abandon old 36″ line in service 50 yr. Development of ind. operations made demand for more water imperative.—*Ralph E. Noble.*

Repairing a Cracked Concrete Flume Without Stopping Water Service. ANON. Eng. News-Rec. **127:** 878 (Dec. 18, '41). Repair of concrete flume 20′ wide and 12′ deep carrying essential supply to important defense plant described. Flume made up of sides of steel sheet piling and bottom concrete slab. Opening developed between piling and slab in section where 24″ stormwater drain passed under flume. Probing disclosed crack about 6″ wide and 4′ long. After several unsuccessful attempts, bottom of flume and crack cleaned by water pressure from fire hose secured to 4 x 4″ timber held in place by ropes against flow of water. Crack then probed to eliminate loose material and slime, 4″ pipe introduced through running water into crack, and soft balls of cement and admixture dropped through pipe and firmly tamped into crack, pipe being raised as filling progressed. Material consisted of 30% by vol. of admixture (nature not disclosed) added to dry cement, resulting mixt. being unaffected by flowing water. Previous lab. tests indicated 3,000 psi. strength in 28 days. After being in place 24 hr., probing indicated that hole had been filled with sound mixt. Other leaks repaired in similar manner.—*R. E. Thompson.*

DAMS

Masonry Dams. *A Symposium.* Proc. A.S.C.E. **66:** 812 ('40) (*see* Jour. A.W.W.A. **33:** 817 ('41)). *Discussion. Ibid.* **67:** 237 ('41). JAMES S. LEWIS JR.: Where improvement of bearing strength is serious consideration, frequently advisable to extend excavation, under gravity section of structure, below any large horizontally disposed seams that would require filling in order to support superimposed load. For exploratory work, diamond core drill far superior to shot drill. Core loss less, and that core which is recovered retains original appearance to greater degree. Cost of line drilling easily may exceed presumed value of any concrete saved by preventing overbreakage of rock. Much line drilling done to no effective purpose.—*H. E. Babbitt.*

Delaware Aqueduct. *VIII. Reservoirs and Dams.* ANON. Eng. News.-Rec. **125:** 688 (Nov. 21, '40). (For abstracts of previous articles of series see Jour. A.W.W.A. **32:** 1413, 1814 (1940)). Project includes 3 impounding reservoirs: (1) Rondout res. on Rondout Creek, tributary of Hudson R.; (2) Neversink res. on Neversink R., tributary of Delaware R.; and (3) East Delaware res. on East Branch of Delaware R. Water from (2) and (3) will be conducted through tunnels into (1), from which Delaware aqueduct will convey mixed water to city. (1) and (2), with 6-mi. connecting tunnel, will be constructed in first stage of development. Second stage, comprising (3) and its 26-mi. connecting tunnel, will be constructed when required. The 3 watersheds lie on westerly and southwesterly slope of Catskill Mts. adjoining watersheds of Catskill system. Region is sparsely populated and largely forested. Valleys suitable for res. sites are long and deep, without low saddles in rims; each requires but a single dam. Sides are steep and bottoms flat, with bedrock overlaid by 100–180′ of irregularly deposited sand, gravel, boulders and clay. In each case, indicated design is earth dam with concrete cutoff to bedrock, and material suitable for construction is available near sites. At (1) it is necessary to provide storage for water supply only. At (2) and (3) sufficient storage must be provided to permit release of compensation water during dry periods in conformity to U. S. Supreme Ct. decree. When both (2) and (3) are completed, compensation water will amount to max. of nearly 200 mgd. First of dams, Thaddeus Merriman Dam, on Roundout Creek, is under construction. It will be rolled earth embankment, with concrete cutoff wall to rock. Height will be about 200′ (above stream bed), crest length, 2,500′, top width, 60′ and max. bottom width, 1,400′, exclusive of loading embankments on toes. Foundation conditions were investigated by borings and 2 exploratory caissons. In deepest overburden, for length of about 900′, cutoff wall will be constructed by sinking line of 20 rectangular reinforced-concrete caissons (including 2 exploratory caissons) from bottom of cutoff trench to sound ledge-rock and sealing caissons to rock and to each other. Deepest caisson penetrated 136.5′ of overburden below bottom of cutoff trench and is 169′ in overall height. Including refilling of cutoff trench and loading at toes, dam will involve about 6,900,000 cu.yd. rolled and other earth embankment and 1,000,000 cu.yd. rock embankment. Creek is diverted through 2,450′ tunnel, concrete-lined to 30′ diam. Spillway will be of side channel type, with 600′ weir. With depth on crest of about 12′, leaving freeboard to top of dam of about 8′, it will pass 100,000 cfs. *IX. Caissons for a Cutoff Wall. Ibid.* **125:** 761 (Dec. 5, '40). Borings, etc., at Merriman Dam indicated maximum depth to rock of 180′ of heterogeneous material, making design and planning for construction of cutoff wall difficult. Sinking line of reinforced-concrete pneumatic caissons and sealing them to sound rock and to each other was judged to be safest procedure, provided that ground water could be so lowered as to keep air pressure within permissible and economical limits. Two exploratory caissons were sunk at deepest part of bedrock valley to investigate practicability and cost of method and to provide addi-

tional information regarding foundation conditions. Caissons were 15′ x 38′ in plan and reached ultimate height of 180′. By pumping from caisson working chambers and from deep well sunk into artesian horizon, artesian head, originally 180′, was lowered about 120′ during sinking of caissons, and both were sealed to rock under air pressure of only 25.5 lb. Continued pumping for 3 mo. after sealing last caisson lowered water additional 40′. Details of sinking operations given. —*R. E. Thompson.*

Enlargement of Alpine Dam. ANON. Western Constr. News **16:** 356 (Dec. '41). Unique sliding joint developed and used by Marin Munic. Water Dist. (supplying water to all principal cities in Marin Co., Calif., across Golden Gate from San Francisco, of which San Rafael is largest) in raising crest of Alpine Dam 31′ for second time. New joint avoids development of excessive stress of original structure during shrinkage and settlement of new concrete slab. Original dam built in '17 on Lagunitas Creek, was 100′ high, gravity concrete structure arched in plan forming reservoir of 1 billion gal. capac. Height increased 8′ in '24 increasing capac. by ½ billion gal., present enlargement will double capac. As rebuilt, crest length increased from 390′ to 550′ and spillway capac. from 5,000 to 7,500 cfs. by construction of 8 new siphons. Principal addn. consisted of slab of concrete extending from rock foundation up downstream face on an 0.8:1 slope, constituting slab of about 25′ avg. thickness. To permit shrinkage during curing of concrete and settlement of new slab, special sliding joint designed and installed at intervals between face of old structure and new slab. Before pouring of new slab begun, concrete ribs 12″ wide and 8″ high built vertically on face of old structure at intervals of about 20′. Ribs faced with 24-ga. galvanized steel strips to eliminate any possibility of bonding between new slab and ribs. After ribs cured sufficiently to carry load of new slab, constr. begun, forming underside of slab about 2½′ from face of old dam. Corresponding to precast ribs on old structure, monolithic ribs 12″ x 1′10″ were formed into new slab. A 1″ x 1″ x ⅛″ angle embedded in butting face of monolithic rib by placing angle longitudinally on face of precast rib as forms were built. At intervals, angle fitted with small pipe connection which extended through sides of rib form and terminated in pressure grease fitting. Just prior to pouring of concrete in new slab, space between angle and sheet metal on precast rib filled with liquid soap by operating soap-filled lubricating gun on grease fittings. During period in which shrinkage and consolidation took place in new slab, liquid soap in sliding joints of rib insured freedom of movement without inducing stress in existing structure. Constr. started in '40.—*Martin E. Flentje.*

Buttress Dam at San Felipe, Argentina. ANON. The Engr. (Br.) **172:** 233 (Oct. 10, '41); Wtr. & Wtr. Eng. (Br.) **43:** 294 (Oct. '41). New barrage works control sporadic overflows from catchment area of 1,230 sq.km. Topographical features of dam site consist of open ravine, slopes, exposed rock stratum, low enclosing heights preceded by fairly extensive valley or basin, and two lateral ridges of no great height. Vol. of water impounded at 841 m. above datum is 81 cu. hectometers, covering area of 1,300 ha. Works consist of main dam, various excavations, supply conduit, spillway channel and certain embankments. Main dam reinforced concrete buttress of Ambursen type; max. length 220 m. and max. height is 25.50 m. Buttresses are on 5.50-m. centers. Wall inclined 45° on upstream surface and 1.17 m. thick at foundation. Since rock near surface, no difficult foundation problems encountered. Probably for first time in Argentine practice, concrete pumped. Concrete thoroughly agitated by pneumatic vibrators. Spillway, constructed on north bank, 170 m. long in form of circular arc. With sill el. at 841 m., has overflow capac. of 1,000 cu.m. per sec. with water level at el. 843 m. Outlet works, on south bank, consist of two lengths of 1.10 m. diam. c-i. pipe. Manually operated valves control inlet water to these pipes. Constr. begun in Apr. '38 and completed in May '41. Total exp. $2,779,000.—*H. E. Babbitt.*

CONCRETE

Application of Vibrators for Measuring Mortar Consistency and Fabricating Mortar Cubes. RAYMOND L. BLAINE AND JOHN TUCKER JR. J. Res., Natl. Bur. Stds. **24:** 2: 103 (Feb. '40). (Research Paper RP1273.) 2 vibrators—1 magnetic, with linear vertical motion; 1 mech. with rotary horizontal motion—employed to compact mortars of varying compns., for various durations and at various frequencies and amplitudes. Effectiveness of treatment judged by (1) reproducibility of avg. strength of 6 cubes in 1 batch, (2) reproducibility of strengths of individual specimens, and (3) appearance of compacted specimen. Std. Ottawa sand mortars possessed advantages over those with 2 or more types of aggregate. Mech. rotary vibrator, designed for investigation, found to give better results than magnetic. Either may be used to measure consistencies of mortars of dryness suitable for compaction by vibration.—*J.R.*

Concrete Repair Methods. CLAUDE GLIDDON. Eng. J. (Can.) **23:** 217 (May '40). Repair methods in use by Gatineau Power Co. described. Adopted after 10 yr. experience with many types. No. of suggestions given in summary form; among them: (1) only experienced labor used in all important repairs; (2) experienced engr. must be present during laying of concrete; (3) crushed limestone and sand generally used, screened gravel preferable where available; (4) min. of cement used consistent with good design, as cement least durable of elements in concrete; (5) water-cement ratio used to give 3,000–4,000 lb. 28-day strength for thicker coverings and between 4,000–5,000 lb. for thinner coverings; (6) greatest possible amount of loose and disintegrated concrete removed, surface cleaned by picking and air-blasting, then water-blasted—after thorough saturation all excess water in depressions removed, followed by blasting with water-cement paste to give thin coat, after ½ to 1 hr. when coat tacky second paste coat applied and final coat after another ½ to 1 hr.; (7) all concrete vibrated whenever possible, not done until ½ to 1 hr. after mixing to allow shrinkage to take place before concrete gets into final position—illustrations show good bond obtained; (8) new surfaces kept continuously wet for 7 days. Directions for sealing various joints given.—*Martin E. Flentje.*

Gunite Repairs. ANON. Wtr. & Wtr. Eng. (Br.) **42:** 93 (Mar. 11, '40). Dam of Newton Water Works 550′ long, constructed of mass concrete faced with precast concrete blocks, profile being of solid, gravity type. Repairs made to prevent leakage and to stop facial deterioration arising from frost action and from chem. action of moorland waters. Disintegrated concrete first cut out, layer of steel wire fabric then plugged on face of concrete and gunite applied in two coats to avg. thickness of 2.5″ to build up impervious facing layer. Filtered water tank near Bolton treated as preventive measure against inward leakage. Walls faced with 1.5 reinforced layer of gunite with 12″ return on floor, and local cementation applied in certain places to fill up joints through which leakage had been taking place. Process used also at Churchdown Water Works for repairing honeycombed concrete in walls of res. Unusual case dealt with near Warrington where foundation of res. consolidated to prevent lifting by subsoil water when tank empty.—*H. E. Babbitt.*

Method Employed in Repairing Disintegrated Concrete Wall. WILLIAM H. SCHNEIDER. Ohio Conf. Water Purif. 20th Ann. Rept. ('40). p. 113. Concrete of uncovered clarifier of Fremont plant disintegrated above water line. Wall chipped down to solid concrete and ¼″ steel plates used as permanent forms for new concrete. Plates bolted in place and butt-welded and, after 2 applications of metallic waterproofing to broken concrete surface, forms filled with following mix: 1 bag cement, 4 cu.ft. 40–60 aggregate, 2 lb. iron compd for preventing shrinkage and 5 gal. water.—*R. E. Thompson.*

Concrete Pipes Solve Drainage Problem at Eastern Airport. ANON. Concrete **50:** 4: 4 (Apr. '42). Due to ground contour, entire housing area drains off through swale over which runway extension will pass. Drainage includes water from airport's sewage disposal plant, of

flood proportions after prolonged rains, creating intolerable condition. Affected area first excavated then ditches dug to carry water around land in which pipes embedded 15′ below on 2′ bed of heavy rock foundation laid as part of WPA project. Double line of reinforced concrete pipe solved difficult problem. Units 72″ inside diam., 6′ long, wt. 11,700 lb. Pipes interlocking and placed in pairs to give adequate 300′ drain.—*Ralph E. Noble.*

Cement as a Fire Extinguisher. ROY CROSS. Science **95:** 275 (Mar. 13, '42). In author's experience with great variety of small fires in oil, metals and other materials, nothing so satisfactory and foolproof as portland cement. Highly successful in extinguishing fires where water, carbon tetrachloride, foam and similar substances unsuccessful. This common, safe and easily available material should be placed at points of danger from fires by incendiary bombs or normal causes. In author's lab., such material provided in easily available kegs. Find it more successful than usual fire extinguishers. Non-combustible and gives off no injurious gases as in case of pitch.—*Ralph E. Noble.*

The Action of Waste Waters From the Milk Industry on Cement Products. F. M. LEA AND G. E. BESSEY. Concrete Constr. Eng. (Br.) (Nov. '39). Expts. carried out at Bldg. Research Station of Dept. of Scientific and Industrial Research and at large-scale exptl. plants erected by Water Pollution Research Bd. of that dept. on treatment of waste waters from milk industry, with object of finding extent to which cement mortars deteriorated when exposed under different conditions in plant treating dairy waste waters. Two different mortars used, one contg. portland and other high-alumina cement. Mortars used in form of cubes. Some portland cement cubes were left untreated; surfaces of others treated with sodium silicate soln., magnesium silicofluoride soln., paint with coal-tar base, or paint with bitumen base. Some high-alumina cement cubes untreated and others treated with magnesium silicofluoride soln. Cubes of each type placed in each of following positions in exptl. plants: (1) in storage and balancing tank for crude waste waters; (2) in primary sedimentation tanks for crude liquid; (3) under surface of filtering medium in two percolating filters; and (4) in aeration tank of activated sludge plant. Position of cubes chosen so that some completely immersed in liquid and others only partially or intermittently immersed. Examd. after exposure for 7 mo. and again after total period of 15 mo. Found that deterioration of portland cement mortars influenced by condition and temp. of effluent, greatest deg. of attack occurring in storage and balancing tank, where acidity, concn. of org. matter, and temp. highest. Under most severe conditions, treatment of portland cement mortar with sodium silicate or with magnesium silicofluoride had slightly adverse effect upon resistance but gave some protection under less severe conditions of exposure. Tar-base paint and bitumen-base paint afforded protection for a time but under more severe conditions paint eventually removed and in some cases mortar then attacked. Only completely satisfactory specimens were untreated high-alumina cement mortar cubes, unaffected under any of conditions of exposure.—*W.P.R.*

War Production Board

Division of Industry Operations

The Production Requirements Plan

Effect of the New Regulations

EDITORIAL NOTE: The material which follows outlines the procedures that manufacturers must follow in order to obtain their supplies of basic materials. Since the availability of finished equipment and supplies to public works is affected by the conditions under which the manufacturers obtain their raw materials, operators would know something about the manufacturers' problems.

Portions of the text italicized (editorially) show how the Production Requirements Plan affects end uses of material such as those used by the operators of public water supply works.

The effect on the priorities system of the new regulations concerning the Production Requirements Plan was explained June 18, 1942 in a statement issued by the Bureau of Priorities of the Division of Industry Operations.

"The Production Requirements Plan is the basic authorization to buy material, and supersedes all other priority instruments in the field it covers," according to J. S. Knowlson, Director of Industry Operations. "The other priority instruments will continue in effect, however, for the groups not covered by PRP, and preference ratings will still be used as directives of delivery on finished products."

The text of the statement is as follows:

The Production Requirements Plan is the chief method of authorizing the purchase of basic materials. With a few exceptions, it is mandatory for all concerns using $5,000 worth of metal a quarter and it may be used by other concerns. Approximately 90 per cent of the metal used will be covered by the plan.

For the third quarter of this year, PRP is based primarily upon one form, PD-25A.

This form is filled out by manufacturers as a specific application for authority to buy materials during the quarter. The PD-25A's will be

reviewed and processed by the End Products Branches, including Branches of the Armed Services, within the limitations of the general policy determinations as set forth by the Requirements Committee. Specific conditions within the individual company will be taken into account, however. The PD-25A will then be returned to the applicant as an authority to buy the amounts of material approved on the form.

Advance overall information already has been gathered from all large metal users on their metal requirements for the third quarter. The facts learned from them, together with information on supply furnished by the Materials Branches of the War Production Board, will be used by the Requirements Committee to determine how metal use can best be distributed.

A third part of the picture is the Allocation Classification System, which will be started during the third quarter so that it may become an effective part of PRP during the following quarter. The Allocation System fits in as follows:

The present PD-25A requires information on the end uses of the applicant's products. However, the applicant often has no way of determining these end uses, especially if he is a sub-subcontractor. And even when he knows the end use, he has had no standard method of stating it on the PD-25A. The Allocation System, designed to rectify this, is an end use code in numerical symbols. Numbers from 1.00 to 23.00 have been assigned to all major classes of military, industrial and civilian uses. These classifications are subdivided as necessary. For instance, class 9.00—power, light and heat—has under it subclass 9.10, electricity; 9.20, petroleum; 9.30, coal and coke; 9.40, gas. In addition, there are Purchaser Symbols such as USN for the Navy. [*See June 1942* JOURNAL, *pp. 967 et seq. for complete outline.*]

Priorities Regulation No. 10 requires that the code be used on orders placed after July 1 and on all previously placed orders calling for delivery after July 31. [*Editor's italics.*] In this way the end use will filter down through all layers of contractors and subcontractors to the concerns buying the basic materials.

As a result, when the applications are made under PRP for the fourth quarter, it will be possible for each manufacturer to state exactly, in terms of the code, what proportion of his products will go to what particular end uses, such as tanks, machine tools or airplanes.

As previously stated, PRP grants authority to buy a definite amount of specific materials and also authorizes a lump allowance for operating supplies. Actual shipments of critical material now under allocation control still will be governed by month to month directions from the War Production Board through the "M" orders covering the various

materials. In brief, the "M" orders continue in effect just as before; except for the substitution of the new Allocation Classification for the various classifications now used. PRP, however, is intended to reduce the problem of allocation under the "M" orders by bringing total demand into approximate balance with total supply. This will make the specific scheduling of shipments the most important function of the "M" order.

Priorities Regulation No. 11, the legal basis of PRP, provides that in addition to companies using less than $5,000 worth of metals a quarter, *the users engaged in the following nine classes of business may continue to work through the existing priority procedures* [*Editor's italics*]:

Transportation of any kind; furnishing of heat, light, power, electricity, gas or *water* to others; mining or quarrying; production, refining, transportation, distribution or marketing of petroleum or associated hydrocarbons; communications; sewerage or drainage; sale of material the user has not manufactured, processed, fabricated, assembled or otherwise physically changed, including sales as a distributor, wholesaler, retailer, warehouse, industrial or mill supply house or scrap dealer; extracting, smelting, refining, alloying or similarly processing metal ores or scrap into raw metal; construction, at the site, of buildings, structures or projects.

A "kitty" will be provided as a margin of safety to take care of errors in judgment or changes in the overall program. *In addition, the Requirements Committee will set aside a percentage of the total supply of materials for the nine exempt classes of users* [*Editor's italics*] and for the users of less than $5,000 worth of metal a quarter. Companies in these groups will continue to use all the regular priority procedures, but WPB will restrict each group of users to the proportion of the reserve created for its benefit.

The form of applying and extending all preference ratings will be made uniform after July 1 in accordance with Priorities Regulation No. 3, as amended June 10, 1942. The amended regulation provides that any preference rating may be extended by suppliers and subsuppliers on orders for material which will be delivered to the person to whom the rating was originally assigned or physically incorporated in products to be so delivered. Companies not operating under PRP may also extend any rating to cover operating supplies such as small perishable tools which will be consumed in processing material to fill the rated order, up to 10 per cent of such operating supplies may be in the form of metals on the Metals List of Priority Regulation No. 11.

Several important priority instruments will continue to be used:

The "P" Orders, which eventually will be greatly reduced in number. In the immediate future, however, certain orders will continue in effect for the users of less than $5,000 worth of metal a quarter and for the

special groups. For instance, *P-46 for the Public Utilities*, and broad orders such as P-148, the Export Order, and P-100 as it applies to concerns not covered by PRP, *will continue* [*Editor's italics*].

PD-1A's may still be issued for capital equipment for all classes of producers, [*Editor's italics*] and for all requirements of the industries not operating under PRP. A PD-1A certificate may be used to obtain a finished item from a company covered by PRP, but the rating cannot be extended by such a producer to get necessary materials for manufacture, since he will be required by the terms of PRP to obtain his basic materials through that plan. Where a rating assigned on a PD-1A is served on a manufacturer outside the terms of PRP (for example, the manufacturer who uses less than $5,000 worth of metal for the quarter), the rating can be extended for the necessary materials.

PD-3A's will be used for military requirements in almost exactly the same way as PD-1A is used. Officers of the Army and Navy will continue to assign the PD-3A certificate for the delivery of finished items. The rating then serves as a directive of delivery—the manufacturer will be required to deliver the finished item in accordance with the degree of preference rating assigned. But if the manufacturer is operating under PRP he cannot get materials for production by extending the rating. Instead, he will reply on PRP. (The degree of Preference Rating and the end use code assigned to the finished items will show up in the manufacturer's application under PRP for the next quarter.)

Project Ratings (*P-19 Series*) will continue to be used for practically all building or construction activities with the usual exceptions of a limited amount of military construction and certain classes of housing.

Limitation (*L*) *and Conservation* (*M*) *Orders* will continue to govern the things a manufacturer cannot make even though he may be able to get the material.

TITLE 32—NATIONAL DEFENSE

Chapter IX—War Production Board

Subchapter B—Division of Industry Operations

Part 978—Utilities Maintenance, Repair and Supplies

EXTENSION NO. 1, AND AMENDMENT NO. 1, TO PREFERENCE RATING ORDER P-46 AMENDED TO MARCH 26, 1942

The War Production Board acted June 23, 1942 to expedite the extension of utility services, such as electricity, gas and water, to thousands of war housing units throughout the country.

The amendment and extension to P-46 include:

1. *Utilities in Canada are brought under the terms of P-46, formalizing arrangements previously worked out by WPB with the Department of Munitions and Supply in Ottawa.*

2. *Material required for utility extensions to all projects rated A-5 or better is assigned the same rating as is assigned to the project itself.*

3. *An A-5 rating is assigned to material required by utilities for protection against air raids, provided such protection is directed by an authorized federal or state agency.*

4. *After July 1, 1942, a preference rating of A-1-c is assigned to deliveries of material required for repair of an actual breakdown of existing utility facilities or required to make reasonable advance provision for such repair. The amount of material that may be acquired under an A-1-c rating is restricted.*

5. *Automatic approval of 250-foot extensions, formerly permitted, is changed to apply only to projects if (1) the buildings affected are wired or piped and ready for service by July 1, 1942, or (2) in the case of new construction, foundations are completed prior to July 1. After July 1, no extension of any length can be made without special WPB approval.*

6. The order, which was to have expired June 30, 1942, has been *extended to September 30, 1942.*

Under an amendment to P-46, *utility extensions to housing projects are assigned the same preference rating as are assigned to the housing projects themselves.* Heretofore extensions to housing projects were specifically

excluded from the automatic rating assigned by P-46. In order to facilitate the use of the preference rating, new procedures have been developed under which utility applications for housing extensions will be reviewed in the field and will be processed simultaneously with the housing project application.

Materials needed for such extensions will be made available as far as possible from the inventories of the utility companies themselves. A catalog listing excess stocks has been compiled by the WPB Power Branch and has been sent to all utilities. To make certain that these materials will go as far as possible, the Power Branch has prepared strict standards for the use of scarce materials.

The new procedure for decentralizing approval of applications for utility extensions will work like this:

The builder will ask his local FHA office to approve the construction of a privately financed war housing project. If his application discloses that it is practicable and necessary to build, he will be given a letter requesting the local utilities who will service the project to prepare an application. The utilities will survey the job and and make applications for permission to construct necessary extensions. Instead of sending this application to Washington for approval as heretofore, each utility will submit it to the FHA office which is reviewing the construction application. From this point on, utility applications and the construction applications will be handled together until they are approved or denied by the field office of the War Production Board in that area. These offices are now, for the first time, vested with authority to approve or deny such applications.

When the Federal Public Housing Authority decides to build a public war housing project, similar steps will be taken, except that this agency instead of the private builder will by letter request the utility to prepare an application to extend its services. The Housing Priorities Branch of the War Production Board, now in New York, which approves or disapproves all public housing projects, will have the final word on utility applications as well. In all cases, when utility extensions are approved, they will automatically receive the same preference rating that the housing project enjoys.

The new plan has been worked out by the Power Branch of the War Production Board in collaboration with the Board's Housing Priorities Branch and federal housing agencies. Utilities are being instructed in the new procedure by an administrative letter from the WPB Power Branch. Local offices of the FHA will be able to give full details to private builders in two or three days.

PREFERENCE RATING ORDER P-46 AS AMENDED TO JUNE 23, 1942

Note: Those paragraphs and phrases (except headings) printed in italics comprise the changes in the Order.

978.1—Preference Rating Order P-46

(a) *Definitions for the Purpose of this Order*

(1) *"Producer" means any individual, partnership, association, corporation, governmental corporation or agency, or any organized group of persons, whether incorporated or not, located in the United States, its territories or possessions, engaged in, or constructing facilities for the purpose of engaging in, one or more of the following services, and includes any such producer whether or not such producer has applied the preference rating herein assigned, and also includes any such individual, partnership, association, corporation, governmental corporation or agency, or any organized group of persons, whether incorporated or not, located in the Dominion of Canada, to whom and in whose name, a copy of this order has been specifically issued:*

(i) Supplying electric power directly or indirectly for general use by the public.

(ii) Supplying gas, natural or manufactured, directly or indirectly for general use by the public.

(iii) Supplying water directly or indirectly for general use by the public.

(iv) Supplying public sanitation services, but not including manufacturers of public sanitation products.

(v) Supplying central steam heating directly or indirectly for general use by the public.

(2) "Material" means any commodity, equipment, accessory, part, assembly, or product of any kind.

(3) "Maintenance" means the upkeep of a Producer's property and equipment in sound working condition.

(4) "Repair" means the restoration of a Producer's property and equipment to sound working condition after wear and tear, damage, destruction of parts, or the like have made such property or equipment unfit or unsafe for service.

(5) "Operating Supplies" means:

(i) Material which is essential to the operation of any of the industries or services specified above and which is generally carried in Producer's stores and charged to operating expense accounts.

(ii) Material for additions to or expansion of property or equipment provided that such additions to or expansion of property

or equipment shall not include any work order job or project in which the cost of Material shall exceed $1500 in the case of underground construction and $500 in the case of other jobs and provided further that no single job shall be subdivided into parts in order to come below these limits.

(6) The terms "Operating Supplies," "Maintenance," and "Repair" include only Material which is essential to minimum service standards and do not include Material for the improvement of a Producer's property or equipment through the replacement of Material which is still usable in the existing installation with Material of a better kind, quality, or design.

(7) "Supplier" means any persons with whom a purchase order or contract has been placed for delivery of Material to a Producer or another Supplier.

(8) "Calendar Quarterly Period" means the quarterly periods commencing on the first day of the first, fourth, seventh, and tenth months of the calendar year and ending, respectively, on the last day of the third, sixth, ninth, and twelfth months of the calendar year, or the Producer's customary accounting periods closest to such periods.

(b) *Assignment of Preference Rating*

Subject to the terms of this order the following preference ratings are hereby assigned:

(1) *Producers*

(i) A-2 to deliveries, to a Producer, of Material which is required by him for the maintenance and repair of production and pumping plant facilities, and to deliveries of operating supplies for such facilities.

(ii) A-5 to deliveries, to a Producer, of Material required by him for the maintenance and repair of all other facilities, and to deliveries of operating supplies for such facilities.

(iii) Subject to the provisions of paragraph (e)(2), to deliveries, to a Producer, of Material required by him for the construction of transmission, switching and distribution facilities necessary to serve new projects bearing a rating of A-5 or better, or to serve new equipment the delivery of which is rated A-5 or better, are assigned the same rating as is assigned to such new project or to the delivery of such new equipment; except that where such project or such new equipment is assigned two or more ratings and both or all of these are A-5 or better, such deliveries to a Producer are assigned the lowest rating which is assigned to such new project or equipment.

(iv) Subject to the provisions of paragraph (e)(2), A-5 to deliveries, to a Producer, of Material required by him for protection against sabotage, *air raids, or other hostile acts*, provided such protection is directed by an authorized federal or state agency.

(v) *On or after July 1, 1942, A-1-c to deliveries, to a Producer of Material required by him for repair of an actual break-down of existing facilities, or to make reasonable advance provisions for such repair, provided that such A-1-c rating shall not be applied to more than 30 per cent of the Material within any class which could be scheduled for delivery in each calendar quarterly period under the provisions of paragraph (f) of this order.*

(2) *Suppliers. The same preference rating is assigned to deliveries, to any Supplier, of Material required for any of the purposes specified in paragraph (b)(1) or to be physically incorporated in such Material so required by the Producer, as is assigned to such deliveries by paragraph (b)(1).*

(c) *Persons Entitled to Apply Preference Ratings.* The preference ratings hereby assigned may, in the manner and to the extent hereby authorized, be applied by:

(1) a Producer;

(2) any Supplier, provided deliveries to a Producer or another Supplier are to be made by him, and are of the kind specified in paragraph (b) and have been rated pursuant to this Order.

(d) *Restrictions on Use of Rating.*

(1) *Restrictions on Producer and Supplier.* The preference ratings hereby assigned shall not be applied by a Producer or Supplier:

(i) unless the Material to be delivered cannot be secured when required without such rating;

(ii) to obtain deliveries of scarce Material, the use of which could be eliminated without serious loss of efficiency by substitution of less scarce Material or by change of design.

(2) *Restrictions on Supplier.*

(i) No Supplier may apply the rating to obtain Material in greater quantities or on earlier dates than required to enable him to make on schedule a delivery rated hereunder or, within the limitations of (ii) and (iii) below, to replace in his inventory Material so delivered. He shall not be deemed to require such Material if he can make his rated delivery and still retain a practicable working minimum inventory thereof; and if, in making such delivery, he reduces his inventory below such minimum, he may apply the rating only to the extent necessary to restore his inventory to such minimum.

(ii) A Supplier who supplies Material which he has in whole or in part manufactured, processed, assembled or otherwise physically changed may not apply the rating to restore his inventory to a practicable working minimum unless he applies the rating before completing the rated delivery which reduces his inventory below such minimum.

(iii) A Supplier who supplies Material which he has not in whole or in part manufactured, processed, assembled, or otherwise physically changed may, in restoring his inventory to a practicable working minimum, defer applications of the rating hereunder to purchase orders or contracts for such Material to be placed by him until he can place a purchase order or contract for the minimum quantity procurable on his customary terms; provided, that he shall not defer the application of any rating for more than three months after he becomes entitled to apply it.

(e) *Application of Preference Rating.*

(1) The Producer and each supplier, in order to apply the preference ratings to deliveries to them, must endorse the following statement, which must be applied on original and all copies of each purchase order or contract for Material, the delivery of which is entitled to the preference rating hereby assigned;

"Rating A————. Material to be delivered pursuant to paragraph (b) ———— of Order P-46, Utilities Maintenance, Repair, and Supplies, with the terms of which I am familiar.

————————————
(*Name of Producer or Supplier*)

————————————
(*Signature of Designated Official*)"

Such endorsement shall be manually signed by a responsible official duly designated for such purpose by such Producer or Supplier or in facsimile form in accordance with Priorities Regulation No. 7, (7 F.R. 1062), and shall constitute a representation to the War Production Board that such Material is required pursuant to the paragraph specified in the endorsement, and that the application of the rating is authorized by this Order.

(2) In addition to the requirements of paragraph (e)(1), a producer in order to apply the preference rating assigned by paragraphs (b)(1)(iii), and (b)(1)(iv), *or in order to withdraw Material from stores or inventory for the purposes specified in said paragraphs*, must, *unless otherwise directed*, communicate with the Power Branch, War Production Board, Washington, D.C., Ref: P-46, supplying in detail

the following information *or such other information as may from time to time be required.*

(i) Description of the project to be built by the Producer, *including a print of proposed line construction, showing size of wire, or pipe, capacity of transformers, and other information relevant thereto.*

(ii) Relation to military needs, war production, public health or safety.

(iii) Copy of customer's *preference* rating certificate or order, and, *in case of materials rated under paragraph (b)(1)(iv),* copy of order of federal or state agency.

(iv) Whether service can be rendered in any other way, or by any other Producer, with use of smaller quantities of critical materials.

(v) Cost of materials.

(vi) Total cost of Producer's project.

(vii) List of materials required for the construction, *including the weight of copper or steel required.*

The Director of Industry Operations will notify the Producer whether and to what extent the application is approved. A copy of such notification shall be furnished by the Producer to any Supplier to evidence the proper rating granted pursuant to the provisions of this order.

(3) A Supplier who has received from two or more Producers or Suppliers endorsed purchase orders or contracts for Material to the delivery of which the same rating has been applied in accordance with this Order, may include in a single purchase order or contract, and (within the limitations of paragraph (d) hereof) may apply the rating to any or all of the Material which he in turn requires to make such rated deliveries or to replace in his inventory Material so delivered.

(4) In addition to the records required to be kept under Priorities Regulation No. 1, the Producer, and each Supplier placing or receiving any purchase or contract rated hereunder, shall retain, for a period of two years, for inspection by representatives of the War Production Board, endorsed copies of all such purchase orders or contracts, whether accepted or rejected segregated from all other purchase orders or contracts or filed in such manner that they can be readily segregated for such inspection.

(f) *Restrictions on Deliveries, Withdrawals, and Inventory.*

(1) No Producer shall, in placing orders, schedule for delivery to him in any calendar quarterly period any items of Marteial (whether or not rated pursuant to this Order) to be used as Operating Supplies or for Maintenance or Repair or any other purpose, the aggregate dollar volume of which shall exceed 25% of the aggregate dollar volume of

the withdrawals of items of Material of the same class from stores or inventory during the calendar year 1940.

(2) No Producer shall at any time accept deliveries (whether or not rated pursuant to this Order) of any item of Material to be used as Operating Supplies or for Maintenance or Repair or any other purpose until the Producer's inventory and stores of items of Material of the same class have been reduced to a practical working minimum. Such minimum shall in no case exceed the aggregate dollar volume of items of Material of the same class in inventory and stores on the most recent date during the calendar year 1940 on which the Producer's inventory was taken.

(3) No Producer shall

(i) during any Calendar Quarterly Period, make withdrawals from stores or inventory of any items of Materials to be used as Operating Supplies or for Maintenance or Repair or for any other purpose, the aggregate dollar volume of which shall exceed the aggregate dollar volume of the withdrawals of such items of Material of the same class during the corresponding quarter of 1940, or at Producer's option, 25% of the aggregate dollar volume of the withdrawals of such items of Material of the same class during the calendar year 1940.

(ii) make withdrawals from stores or inventory of Material to be used for additions to or expansion of property or equipment, and no Producer shall, in the case of contract construction, accept delivery of Material for such purposes, unless

(a) the Producer's job or project is under construction and 40% of the total dollar value of the construction thereof was installed on December 5, 1941; or

(b) the cost of materials for the work order, job or project is less than $1,500 in case of underground construction and $500 in the case of other jobs; *provided*, however, that no single work order, job or project shall be subdivided into parts to come below these limits, and, *provided*, that in no event shall lines be extended for the connection of new consumers *except in the case of extensions not exceeding 250 feet to buildings which were wired or piped ready to receive service prior to July 1, 1942, or, in the case of new construction, where the foundation under the main part of the structure was completed prior to July 1, 1942.*

(4) Notwithstanding the provisions contained in paragraphs (f) (1) (2) and (3), a Producer may:

(i) in any Calendar Quarterly Period increase the aggregate dollar volume of scheduled deliveries of Material for the Maintenance

and Repair of, and for Operating Supplies, for, generation, production, and pumping facilities, and withdrawals of Material for such use over the limits prescribed in paragraphs (f) (1) and (f) (3) respectively proportionately to the increase in system output in the preceding Calendar Quarterly Period over the system output in the calendar quarter of 1940 corresponding to such preceding Calendar Quarterly Period; and

(ii) schedule for delivery in any Calendar Quarterly Period items of Material which will increase the aggregate dollar volume of inventory of Material for the Maintenance and Repair of, and for Operating Supplies for, generation, production and pumping facilities over the aggregate dollar volume of Material in inventory on the most recent date during the calendar year 1940 on which the Producer's inventory was taken, proportionately to the increase in system output during the preceding Calendar Quarterly Period over the system output in the Calendar Quarterly Period of 1940 corresponding to such preceding Calendar Quarterly Period; and

(iii) schedule for delivery to him in any Calendar Quarterly Period consumers' meters and house-regulators or make withdrawals from stores or inventories of such meters and house-regulators in an amount not in excess of 25% of the number of such meters or house-regulators condemned and destroyed by the Producer in 1940, (or, at the Producer's option, not in excess of the number of such meters and house-regulators condemned and destroyed in the corresponding quarter of 1940) plus the number of meters and house-regulators necessary to serve the net increase in customers occurring in the current quarter. For the purposes of this subparagraph (iii), withdrawals of meters and house-regulators shall not include meters or house-regulators put in service to replace meters and house-regulators removed from service; and

(iv) in order to provide Material for unavoidable and emergency situations in cases where the inventory of a class of Material exceeds a practical working minimum, accept in any Calendar Quarterly Period deliveries of any short item of Material within such class, such deliveries, however, not to exceed 5% of the dollar volume of withdrawals of Material of the same class in the calendar year 1940; and

(v) schedule Material for delivery in any Calendar Quarterly Period, or accept deliveries, or make withdrawals in such period of Material necessary for the Maintenance or Repair of the Producer's property or equipment which is damaged by acts of the

public enemy, sabotage, explosion, fire, flood or other climatic conditions, *provided*, that if the restrictions in paragraph (f) (1) (2) or (3) as modified by the provisions of paragraph (f) (4) (i) (ii) (iii) and (iv) are exceeded because of the scheduling or acceptance of such deliveries, or withdrawals, or full report therefor together with reasons therefor shall be made immediately to the Director of Industry Operations.

(5) The Director of Industry Operations may, on the application of any Producer, authorize such Producer to exceed the restrictions on deliveries, withdrawals, and inventories set forth in this paragraph (f). Nothing herein contained shall be construed to affect in any way any specific authorizations or approvals issued by the Director of Industry Operations pursuant to Preference Rating Order P-46 prior to the effective date of this Amendment.

(6) The provisions of this paragraph (f) shall not apply to material obtained through the application of the ratings assigned in paragraphs (b)(1)(iii) or (b)(1)(iv), or to material withdrawn from stores or inventory for the purposes specified in said paragraphs; *and the provisions of paragraphs (f)(1), (f)(2) and (f)(3)(i) shall not apply to fuel, water purification chemicals, wooden poles or wooden crossarms.*

(g) *Audits and Reports.*

(1) Each Producer and each Supplier who applies the preference ratings hereby assigned, and each person who accepts a purchase order or contract for Material to which a preference rating is applied, shall submit from time to time an audit and inspection by duly authorized representatives of the War Production Board.

(2) Each Producer and each such Supplier shall execute and file with the War Production Board such reports and questionnaires as said Office shall from time to time request. No such reports shall be filed until such time as the proper forms are prescribed by the War Production Board.

(3) Each Producer shall maintain a continuing inventory of Material included in stores accounts.

(h) *Communications to War Production Board.* All reports required to be filed hereunder and all communications concerning this Order, shall, unless otherwise directed, be addressed to:

"War Production Board
Washington, D.C. Ref: P-46"

(i) *Violations.* Any Person who wilfully violates any provision of this Order or who by any act or omission falsifies records to be kept or information to be furnished pursuant to this Order may be prohibited

from receiving further deliveries of any Material subject to allocation, and such further action may be taken as is deemed appropriate, including a recommendation for prosecution under Section 35 (A) of the Criminal Code (18 U. S. C. 80).

(j) *Revocation or Amendment.* This Order may be revoked or amended at any time as to the Producer or any Supplier. In the event of revocation, deliveries already rated pursuant to this Order shall be completed in accordance with said rating, unless the rating has been specifically revoked with respect thereto. No additional applications of the rating to any other deliveries shall thereafter be made by the Producer or Supplier affected by such revocation.

(k) *Applicability of Priorities Regulation No. 1.* This Order and all transactions affected thereby are subject to the provisions of Priorities Regulation No. 1, as amended from time to time, except to the extent that any provision hereof may be inconsistent therewith, in which case the provisions of this Order shall govern.

(l) *Expiration Date. This order shall continue in effect until September 30, 1942, unless sooner revoked.*

Issued this 23rd day of June, 1942.

(signed)
J. S. KNOWLSON
Director of Industry Operations

Users of individual PD1-A certificates may now inclose with their application blank a self-addressed postcard which will be returned by the War Production Board with the case number of the application stamped on it. Reference to this case number will then facilitate handling of subsequent inquiries relating to the application. All inquiries concerning applications should be submitted in writing.

Coming soon will be a supplement to this issue of the Journal. Members should watch for this supplement which will contain the speech by J. A. Krug, Chief of the Power Branch of the War Production Board, given at the Chicago Conference on Wartime Water Works Problems. The supplement will also contain the latest information on Selective Service and deferment of key water works men as well as other war information.